FINAL REPORT

19 June 1970 - 20 June 1971

to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Office of Technology Utilization
(Code KT)

Annual Review

Biomedical and Public Sector

Technology Application Team Program
for
NASA Contract NASw-2055

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APPLICATIONS OF AEROSPACE TECHNOLOGY IN THE PUBLIC SECTOR

An Annual Review

of the

BIOMEDICAL AND PUBLIC SECTOR
TECHNOLOGY APPLICATION TEAM PROGRAM

for

THE TECHNOLOGY UTILIZATION OFFICE
(CODE KT)
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For the Period

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by the

Technology Application Group

THE GEORGE WASHINGTON UNIVERSITY
Medical Center
Biological Sciences Communication Project
Washington, D.C.

as the

Final Report for NASA Contract NASw 2055

The Technology Application Group is directed by Herbert N. Cantor, with assistance from Todd Anuskiewicz, John Johnston, Robert Zimmerman and Winifred Griffin.

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INTRODUCTION

In response to the recognition that much of the technology developed to meet aerospace needs is potentially applicable to broader public needs, the NASA Technology Utilization Office has sponsored the development of mechanisms for facilitating a systematic transfer of NASA technology to nonaerospace sectors. Major emphasis has been placed on establishing viable methodologies and mechanisms for ensuring successful applications of technology in the public sector.

It is intended that this report provides an overview of the Application Team Program, one of the major operational programs and associated technology applications activities sponsored by the TU Office. In this activity, NASA is cooperating with over 175 organizations, professional groups, medical research and clinical centers in joint problem-solving efforts which provide a basis for identification and application of aerospace derived technology for broad public benefit. In the report, an effort has been made to describe the total context in which the technology applications are being made.

The first part of the report focuses on the context of some of our complex society's needs. The emphasis here is to describe significant problems for which applications of new or improved technology are being sought.

The second part of the report reviews those areas of technology in which NASA has made significant contributions, which, with others, provide the broad base of technical expertise proven of value in the nonaerospace context. Participants in the NASA program regularly utilize such expertise in their search for solutions to nonaerospace problems.

The third part of the report describes the Application Team Program. Specific achievements by these activities, during the one year period covered by this report, are described in the 4th and 5th parts.

The sixth part of the report discusses a wide range of program support activities designed to assist NASA and the Application Teams in their technology applications efforts.

The seventh part of the report discusses those facets of the Application Team Program methodology which will receive continued emphasis in the future.

Requests for further information may be directed to:

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Washington, D.C. 20546

TECHNOLOGICAL REQUIREMENTS IN THE NONAEROSPACE (PUBLIC) SECTOR

TECHNOLOGICAL REQUIREMENTS IN THE NONAEROSPACE (PUBLIC) SECTOR

BIOMEDICAL SECTOR NEEDS

During the past decade, the costs of quality medical care have risen steadily and steeply, and the cost of hospital care is now rising at a rate twice that of other cost-of-living categories. The growing population, the rising expectation of the general public for improved health care, and a larger elderly population place severe strains on the present health care delivery system. An increasing proportion of high-quality medical care is in a few medical centers, and emergency medical services have deteriorated severely or are nonexistent in many urban and rural areas. These problems will not be solved merely by supplying more doctors and nurses. There is need for a comprehensive review of the situation and for the introduction of new skills and new technologies; this would probably bring about a restructuring of the entire system for health care delivery in the United States. Throughout the country there is an obvious need for intensification of the often feeble efforts to apply technological capability to the solution of health service problems. Rather than being a true system for health care delivery, which implies a system oriented towards education, prevention and early detection, the health care system today is oriented more towards the treatment of manifest injury and disease.

The life expectancy in the United States is still below the age of 70, essentially unchanged since 1949. The life expectancy of males in the U.S. is now in 22nd place among the countries of the world, and the life expectancy of females is in 10th place. This relatively low position is due in part to the high mortality rate of men in their 40's; in part to the high infant mortality rate; and in part it is a result of the wide variation in the quality of medical care available to different portions of the population.

The national infant mortality rate, about 20 deaths during the first year per 1000 children born alive, is almost twice that of Sweden and the other Scandinavian countries. This rate falls far below that of the majority of developed nations. These discouraging figures find their basis to some extent in a lack of participation in the health care system of major segments of the population. In New York City, during 1966, approximately 40 percent of the women who gave birth had not seen a doctor during pregnancy. By contrast, in Scandinavian countries medical assistance is regularly available to expectant mothers, and a midwife system is common; yet there is a severe shortage of doctors in Scandinavia, whose citizens visit a physician only an average of three times a year. In the U.S., the average is five visits per year. Thus, it might be inferred that a small percentage of Americans is over-utilizing the limited supply of physicians and health facilities. While this situation is often considered to be socio-economic in nature, it may be partially alleviated by technologies which will permit better use of current medical and clinical resources.

Expansion of General Health Care Capability. An obvious necessity exists for the expansion of health care delivery systems to take care of a large segment of the population in rural and low population-density areas, in addition to those in central cities. A key issue is that many remote areas lack

an economy sufficient to support an active medical profession--hospitals, nurses, ambulances, and other essential components for adequate health service systems.

As an example, the seven southwestern countries of New Mexico which cover 32,000 square miles form an area larger than the combined five New England states. While the estimated population of the New Mexico area is over 130,000, if the population of the five largest towns were excluded the population density would be less than one person per square mile. There are 68 medical doctors in this area but 33 are located in the largest town, and transportation is difficult.

A system is being developed to meet these problems, which could bring both routine and emergency medical care to people beyond the reach of the limited supply of physicians. Paramedical personnel and nurses could provide medical instrumentation to the patient. As visual information can be vital to a proper diagnosis, a television system would enable a physician in a distant location to observe the patient as well as to review the patient's physiological indicators, while at the same time guiding the testing of the patient and consulting computer-stored medical histories. If necessary, the physician would recommend action to be followed, such as the administration of a drug, or simple sutering by trained paramedical personnel. If there were need for the patient to be transported by helicopter to a centrally located hospital, during transit biomedical telemetry systems could transmit vital parameters about him to the hospital, so that critical time would not be lost in initial diagnosis.

Another major approach to providing improved medical services to urban and rural communities is the automated multiphasic health testing (AMHT) center. These centers utilize paramedical personnel in conjunction with medical instrumentation and automated laboratory equipment to assess an individual's physiological condition. The primary purpose of multiphasic screening is to provide for early pathologic detection, to alert people to pathologic conditions of which they may be unaware. Improved medical electronic instrumentation and automated systems for blood analysis would allow a few trained technicians to perform many complicated tests economically, accurately, reliably, and rapidly, on a great number of people. When coordinated with a remote information processing facility, these instruments would permit relatively small, localized, and economically operated facilities to provide preliminary patient screening in both urban and rural areas. Records would be entered automatically into the patient's computer memory record along with information on his medical history and physical condition at the time of diagnosis. The computer would then compare the test results with the normal ranges for age and sex to determine if an abnormality exists. If an abnormal condition is identified, the patient would be referred to a physician for more thorough diagnosis and treatment. By reducing the average time and cost per test, a comprehensive physical examination can be performed at a moderate cost. As time passes, trends will be established for individual patients, and it is hoped that trend detection will make an important contribution to preventative medicine in the next few years.

Intensive monitoring of patients in critical or potentially terminal conditions is gaining rapid and wide-scale implementation in hospitals. The information gained by continuous monitoring of the physiologic variables

of postoperative or critically ill patients, as well as premature infants, can contribute to better patient care and a substantial reduction in mortality rates. Such monitoring systems can record changes in many physiological variables; can analyze and note their progression; and alert appropriate medical personnel should any of the monitored parameters vary from a predetermined range of values. Thus, corrective action is possible before irreversible damage occurs. These monitoring systems can also be used to control life-support systems, such as respirators, and fluid or drug infusion devices. The development of improved, noninvasive sensors and transducers, as well as improved data transmission and processing techniques, will contribute to improved, more comprehensive patient care by permitting physicians to more accurately assess a patient's progress toward recovery.

Cardiovascular Diseases cause 54 percent of all deaths in the United States, according to current statistics, and more than 150,000 persons apply annually to the Social Security Administration for disability pensions because of cardiovascular disorders. A major portion of medical research is focused on developing, understanding, and treating cardiovascular diseases. New or improved technology is urgently needed to support cardiac research and related therapy. Currently, artificial pacemakers are making it possible to sustain the lives of 13,000 patients per year, suffering from heart block or chronic heart rhythm disturbances. Improved pacemaker electrode installation to avoid a major surgical procedure leads to a requirement for an electrode to be implanted in the heart muscle through a hypodermic needle inserted through the walls of the chest and heart. A technique of carotid nerve stimulation, developed by NIH, eliminates or provides rapid relief from angina attacks. The process could be enhanced by an improved, biologically compatible, flexible electrode. Techniques for automating the analysis of EKGs recorded during a patient's normal daily activity will enable physicians to more accurately determine a patient's susceptibility to a heart attack and initiate preventive measures promptly.

Although coronary cine-angiography has been used for several years to evaluate the heart's contractile cycle, the reading and interpretation of the films has been a very time consuming procedure. Computerized pattern-recognition techniques have now been developed which scan the angiographic film, recognize a set of "branching points" on the myocardium, and, by tracing the relative movement of these points over a period of time, the technique can determine cardiac output, the amount of work being performed by the heart, and the efficiency of the pumping action. A desirable computerized system for the evaluation of cardiac function would be one which scans the cine-angiogram, and then produces a display which allows a physician to watch a "movie" of a patient's beating heart and to identify scar tissue, aneurysms or other faults.

Impedance cardiography also shows promise as a diagnostic technique for noninvasively assessing cardiac output. As it does not require the injection of dye or the insertion of a catheter into the heart, it could be used safely and economically to determine cardiac output either in health screening programs, or in the continuous monitoring of surgical, postsurgical, or severely traumatized patients. Further developments in all of these diagnostic tools is highly desirable.

Radiography. X-rays and radioisotope techniques are essential to the diagnosis of a wide range of disease conditions. Equally vital is the treatment of cancer with high energy radiation. Radiology is heavily dependent on the state-of-the-art in physics and electronics, as well as clinical medicine. Current X-ray procedures rely upon ionizing radiation for only a small fraction of the energy required to produce diagnostic images. In X-ray imaging, the remainder of the energy is created by phosphorescent screens; similarly, image amplifiers are essential to fluoroscopic studies. The use of electronic storage systems designed to retain an image from a cathode ray tube display rather than from a film should allow for improved image enhancement, transmission, and storage. Improved instruments to detect and measure ionizing radiations with improved accuracy, particularly the lower energy ranges, are also essential to controlling the amount of therapeutic radiation received by a patient. It has been observed that a 10% change in the amount of radiation delivered to a cancerous tumor can cause nearly a 60% change in the remission rate. An important factor in the reduction of patient radiation exposure is the development of short-lived isotopes, such as Technetium-99 and Iodine-123, which permit a variety of examinations at low radiation levels of body organ systems with clear definition of image. Also of growing importance are computer image enhancement techniques, and high resolution films for autoradiography.

Nearly 70% of all cancer patients are receiving some form of radiologic therapy; yet, as successful treatment of cancer is highly dependent on early discovery, the search for improved detection and treatment techniques continues. Although a technique for freezing and storing white blood cells could prove invaluable to techniques for treating leukemia patients, one major complication has been to maintain a constant rate of cooling in order to freeze the cells without rupturing the cell walls. A technique which uses an electronic temperature sensing and control system would help make the process possible. Improved film emulsions with smaller grain size, higher resolution, and greater sensitivity are needed to improve autoradiographic studies vital to cancer research. Improved techniques of whole body scanning to detect selective isotope uptake in research animals and an improved lens system for a microphotospectrometer are needs related to cancer research programs. Also needed are techniques for improving the detection abilities of ultrasonics, thermography, and Xerography: all are nonionizing radiations which might be useful for tumor detection without subjecting the patient to damaging X-rays.

Pulmonary disease is the basis of claims of about 50,000 people per year who apply to the Social Security Administration for disability pensions. Onset of the disease often occurs when claimants are in their 30's and the average total pension paid throughout the lifetime of one so disabled approximates $70,000. Evidence currently suggests that a great deal of progressive lung function impairment could be retarded or even prevented by timely and consistent treatment. A significant part of the problem is in determining the existence and the extent of pulmonary impairment. Similarly, it is necessary to judge the therapeutic value provided by various techniques. The most widely used methods for examining respiratory function are bulky and cumbersome, and prevent the patient from moving about or exercising in a normal manner. Several new techniques which allow the patient greater freedom are beginning to be widely used clinically, and could significantly affect

the lives of numerous patients. Further development and clinical evaluation of these techniques is required.

Impedance pneumography is a technique utilizing an impedance bridge and a small transmitter, which allows a physician to measure the volume of air inhaled and exhaled, the inspiration and expiration patterns, and the respiration rate while the patient is engaged in any type of activity or exercise. The instrumentation package can be worn by the patient on a belt or carried in a shirt pocket. Miniature, high-speed mass spectrometer systems may enable a physician to determine the efficiency with which respiratory gases are absorbed and released by the lungs. Precision, low resistance fluidic or ultrasonic flowmeters could also make a valuable contribution to the study of the patient's pulmonary condition. Utilized in a comprehensive, systematized care program, such devices will enable therapists to determine continually and with greater accuracy the efficacy of the various types of available treatment.

Respiratory disorders also contribute significantly to the high infant mortality rate. However, respiratory function monitoring devices developed for use on adults have not always been adaptable to infants. Several systems have recently been developed specifically for infant monitoring, which could reduce the mortality rate associated with respiratory disorders. Occasionally it is necessary to place an infant in an atmosphere with a high oxygen concentration. While this may be required for only a few days, if the oxygen content of the respired air is too great for too long a time, such a situation can result in permanent blindness. A small oxygen concentration monitor has been developed which can measure the amount of oxygen in the air being delivered to the infant. Originally designed to monitor the atmosphere of a space capsule, the device is now commercially available. Its ability to immediately warn nursing personnel of excessive oxygen concentration could significantly reduce the number of children blinded under these circumstances.

Surgery. As new and more complicated surgical techniques evolve the amount of time that the patient is on the operating table as well as the time he is under anesthesia are increasing. Hence, of great importance are more rapid, accurate, continuous techniques to assess the depth of anesthesia and the physiological condition of the patient. As the anesthetic suppresses the action of many of the body's physiological and metabolic control systems, it is the responsibility of the anesthesiologist to monitor and supplement, if necessary, the control normally exercised by these systems. Most patients undergoing major surgery must have their respiratory function mechanically assisted while they intermittently receive the anesthetic gas as required. Thus, continuous and accurate information on the flow rate, chemical composition, and volume of inspired and expired gases, as well as data on the blood gas saturation and pH, can greatly enhance the anesthesiologist's ability to monitor and control the patient's condition. This would significantly increase the patient's chances of survival. An accurate flowmeter and fast-reading mass spectrometer are technologies which may be able to provide the necessary capability, if their capabilities are extended to meet medical requirements.

Clean room techniques have been adapted to hospitals, reducing by a factor of 100 the quantity of airborne bacteria and particulate matter in

areas such as operating rooms and recovery suites. Improved continuous monitoring techniques are required to assure the maintenance of low bacteria and particulate counts. This significant reduction in airborne bacteria and particulate matter greatly reduces the possibility of latent bacteria becoming introduced into the body during open heart or prosthetic implant surgery. These bacteria may lie dormant for months or years before causing a low grade infection, eventually leading to a serious infection or implant rejection.

Rehabilitation of Handicapped. The Department of Health, Education, and Welfare estimates that 12 million Americans have disabilities which limit them in the work they can perform. These handicapped persons include 250,000 in wheelchairs, and 2 million orthopedically impaired children. Economical, self-propelling wheelchairs powered by lightweight motors and power supplies, as well as innovative devices to permit chair control, are required. By increasing the mobility and self-confidence of the handicapped, improved efficient wheelchairs enable participation in a wider range of activities.

Small motors, controls, and power supplies are required to activate self-contained orthopedic limbs for amputees. Since these devices are active prosthetics which the wearer can use to control motion and action, they should contribute to functional rehabilitation to a much greater extent than the passive cosmetic prostheses used for many years. A wide range of pressure measuring devices are needed to measure the forces exerted on and by prosthetic limbs, thus contributing to improvements in their design and functional capability. Also needed are other movement-sensing devices which can assist physical therapists in objectively evaluating the progress made by patients undergoing rehabilitation. The evaluation of muscular control and functional ability is often carried out using electromyographic (EMG) equipment to detect the electrical signal generated by muscle tissue when it is actively exercised or passively moved. There is a need for improved electrodes and signal processing techniques to provide more clinically useful information from EMG techniques.

The widespread use of biologically compatible plastics and metal alloys to replace damaged bone, blood vessels, and tissue has begun. The materials are being used in arterial and venous shunts, cerebrospinal-venous shunts, artificial heart valves, and to replace necrotic bones and joints. There are needs for materials to reduce the incidence of bedsores and to provide for the quick fitting of prostheses, and for the fabrication of temporary support devices.

Medical Systems Management. Computerized information techniques can improve and streamline hospital record-keeping by maintaining accurate, up-to-date files of patient's medical histories. By providing a systematic review of many physiological parameters, a physician may detect the progressive development of a disease at an early stage, rather than overlooking it until after the disease has reached a critical, potentially fatal stage. There are requirements for computer systems which can maintain records and results of clinical laboratory and radiation tests; schedule the testing of a patient to maximize utilization of hospital facilities; provide central supply and inventory control; and attend to many time-consuming, laborious, administrative tasks. Such systems would increase the efficiency of hospital personnel

and operations significantly, as well as provide for more effective utilization time. In several cases, the improved records of lab tests performed have enabled hospitals to recover the cost of their computer systems within the first year through accurate, complete, and timely billing. The improved efficiency of lab operations has reduced the cost of individual tests three and fourfold, which should result in significant savings to many patients.

Systems management information center techniques are needed to permit periodic and detailed reviews of project progress. Such centers are being applied as an aid to hospital management personnel in the control of hospital expansion projects. Such information centers have already been used in other areas to assist city management teams in building new airports, and in implementing other public works expansion programs.

Summary. The medical and engineering communities have been responsive, in part, to these and other changing needs. Early detection of disease and preventive medicine, expanded health care facilities keyed to regional requirements, and prepaid health care programs are developing medical practices geared to meet the needs of the expanding population. Physicians are beginning to delegate routine procedures to paraprofessional personnel, thus freeing the physician to concentrate on tasks that require his extensive background, education, training, and experience. A severe and possibly increasing shortage of trained medical personnel continues, necessitating development and exploitation of new technology to assist medical personnel in providing improved medical care to larger numbers of people.

The application of new technologies to urgent problems in the biomedical field is often difficult to achieve. Technological innovations must survive a maze of obstacles in the governmental, industrial, academic and medical complex in order to have some impact on the delivery of health care services. This state of affairs is complicated by a general lack of knowledge of the mechanism by which biomedical research moves through development into more effective instrument devices and systems. The task of transfer in such an environment is difficult, but the systematic effort to find, evaluate and apply new technology must continue in order to free the doctor for more humanized, effective, and hopefully, less costly care of the patient.

PUBLIC SECTOR NEEDS

In our growing economy, social and environmental conditions that were adequate in past years no longer meet today's standards or requirements. For example, in 1964 about 15 percent of the population was considered to be living at or below the poverty level. This estimate has risen to well over 20 percent; however, it should be noted that in the intervening years, the standards of measurement have also risen. Standards of housing and the urban services characteristic of former years are no longer considered satisfactory. The populace itself, spurred on by the rising economy and an awareness of advances in science and technology, continually upgrades the minimum requirements. New unmet human and community needs result both from changing social patterns and rising desires of the population.

The Report of the National Commission on Technology, Automation, and Economic Progress defines these unmet needs in two categories. The first is

private, the needs of those living in poverty; the second is the public requirement of the total populace. The public needs are related to the readily acknowledged problems of housing, medical care, air and water pollution, mine safety, crime, and transportation, to name some of the most urgent.

Crime, as shown by the public opinion polls and political campaigns, is of great concern to both urban and rural Americans. According to the Commission on Law Enforcement and Administration of Justice, the average likelihood of a serious personal attack on any American in a recent year is about 1 in 550. Nearly half of all reported robberies take place on streets and about half of these are armed robberies.

Other frequent forms of major crime included employee theft and embezzlement, drug use, fraud, homicide, rape, and auto theft. The economic and social impact of crime is staggering. Crime estimates for the year 1965 indicate 9,850 homicides; that half the 49,000 deaths in automobile accidents were attributable to negligent manslaughter or drunk driving; and that 290 women died from illegal abortion complications. The total economic loss in earning power was more than $1.5 billion calculated forward from the time of death.

Public concern about improvement of the entire criminal justice system resulted in the Omnibus Crime Control and Safe Streets Act of 1968. This act created a federal agency to coordinate and intensify law enforcement efforts, The Law Enforcement Assistance Administration (LEAA), and also made available a significant source of federal funds to be used by law enforcement agencies throughout the nation.

It is suggested that law enforcement, criminalistics, and the administration of justice would benefit from the increased application of modern technology. Specific recommendations made by the Commission reflect the need for technology in such areas as computerized command and control facilities; semi-automatic fingerprint systems; small, inexpensive portable radios for foot patrols and automatic car locator systems.

In fiscal years 1969 and 1970, LEAA provided almost $2 million to 19 states and the District of Columbia, specifically intended to improve crime laboratory (forensic) services. Funded too, are the development of new technologies for police, such as a lightweight transceiver, heroin detection methods, airborne surveillance television, new methods for coping with bombs, and standards for police equipment. Intensified application of modern technology will be required to increase the efficiency of police effectiveness as well as that of our judicial system and forensic science capabilities.

Housing Construction and Rehabilitation is insufficient in meeting public needs. It has been estimated that more than 1,200,000 new housing units built each year merely keep pace with the demand caused by population growth, the demolition of old structures, and population mobility. New construction does not take care of the demand generated by replacement of substandard housing, with the result that those living in the substandard continue to do so.

Several factors serve to create institutional rigidities that hinder wide technological breakthroughs. Included are the housing industry, which often

is unwilling to invest capital in innovation that represents a risk; the unions, which create resistance to innovations which may lead to loss of jobs; the mortgage bankers, who are not venturesome in providing risk capital; the construction industry suppliers, who bear a high amount of risk in developing new products; and the consumer, whose generally conservative taste in housing styles inhibits efficient and innovative construction techniques.

The typical construction firm is small and unable to support a research and development program. Little pressure is put on construction firms or unions to develop and adopt new methods. Contractors continue to follow the basic methods of construction even though they now make use of power equipment in site preparation and lifting of materials, as well as using improved hand tools. Special interest groups, anachronistic zoning regulations and building codes, and fragmented local governments help frustrate incentives.

There are a number of innovative programs which hold promise for the future, for example, HUD's Operation Breakthrough program, and the New York State Urban Development Corporation. The Operation Breakthrough program is funding research and pilot programs of innovative building. The Urban Development Corporation was created for the purposes of planning and developing the urban areas of New York State. In order to achieve this goal, extensive powers were given to UDC. It has the power to override obsolete zoning and building codes. Above all, the Urban Development Corporation, unlike any other Government agency, has the major responsibility and the complete and continuing authority for the development of a project from land acquisition to final construction. The powers given to UDC enable it to deal with many of the complex problems which often thwart housing and urban development programs.

There are a number of technologically related areas in which innovative developments could contribute greatly toward overcoming the obstacles to meeting housing requirements. These areas include:

- Detection of lead in paint
- Better techniques for rehabilitation buildings
- Fire-extinguishing and fire- and smoke-detecting systems
- Better exterior surface materials
- Better fireproofing materials
- More efficient electrical distribution systems
- Improved sewage disposal systems
- Better insulation materials to decrease heating costs
- Improved, lightweight, and fire-resistant structural materials
- Better nondestructive testing and joining techniques
- Coatings, heat-resistant materials, and chemical additives for improved strength in structural steel
- Improved spray foam application techniques
- Research on fire-retardant foams

Mine Safety has recently received wide attention due principally to the mine disaster at Farmington, West Virginia, in 1968 in which 78 men were killed. This tragedy provided the impetus for the Federal Coal Mine Health and Safety Act of 1969. This Act represents a major stride in occupational health and safety protection for coal miners. In 1970, the acting director of the Bureau of Mines, Dr. Earl T. Hayes, said: "An outstanding feature of the new law is

its recognition of technology's vital role in providing better health and safety conditions for American coal miners." He added that the new law was expressly designed to stimulate innovation.

Congress also raised the Bureau's three million dollar annual safety research budget to more than 20 million dollars. Research has included a three million dollar rescue and survival system, an explosion-proof hyperbaric mine, and remote-control vehicles to explore damaged, gas-filled coal mines. Unfortunately, the results of this work were not available in time to save the 38 men who died on December 30, 1970 in an explosion at the Finley Brothers coal mine near Hyden, Kentucky. In the 14 months since the 1969 health and safety law took effect, 297 miners have been accidentally killed. Numerous others have fallen victim to pneumoconiosis, commonly called black lung, an incurable lung disease caused by inhaling coal dust.

Research in coal mine safety is required in numerous areas:

- Application of lasers for gas monitoring devices
- Infrared scanners to detect loose roof rock
- Instantaneous explosion-quenching systems
- Fire detectors
- Chemicals to stabilize roofs and walls of passageways
- Mine communications
- Borehole inspection devices
- Rock stress indicators and detectors
- Miner breathing devices
- Safety-approved underground illumination systems

Water Pollution results primarily from the great urban and industrial expansion of recent years. Midwest Research Institute predicts that if water pollution continues to increase at its present rate in the United States, the quality of every fresh-water source in the country will be seriously threatened within the next ten years. Typical pollutants include heat-thermal pollution; solid material; radioactive wastes; toxic substances; substances that affect the water's taste, color, or odor; and materials that consume the dissolved oxygen in water. A major index of water quality is in large part determined by the water's oxygen content: high waste loads dumped into water resources require large amounts of oxygen for decomposition. Such high waste loads deplete oxygen with attendant reduction or total loss of essential fish life and the development of foul odors.

Thermal pollution of water, a major ecological problem, is caused primarily by the electricity generating plant. Water is used to cool the condensers; the average increase in temperature of the cooling water is 13°F. The discharged heated water speeds up the biological and chemical processes and changes the life cycles of fish. A change in the ecology of the area eventually results. The potential impact of thermal discharge is indicated by an estimate that our requirements for electric energy are doubling every 10 years.

Municipal water pollution problems are comprised of the interaction of various adverse factors. Less than a third of the nation is served by an adequate sewer system coupled with a waste treatment facility; about a third is served by inadequate facilities; the final third has no system at all. Municipal wastes are responsible for much of the nutrient pollution believed

to result from phosphates. The cost to the public of solving the municipal waste problem has been estimated at $10 billion over the next five years.

Water pollution can be reduced by massive capital investment and by introducing innovative technology to solve various problems. Equipment and techniques that could play important roles in providing solutions are:

- Sludge dewatering equipment
- Improved water quality monitoring systems
- Phosphate removal techniques
- Thermal pollution removal methods
- Improved flowmeter systems
- Algae growth control
- Improved filtration processes
- Improved oil dispersion or removal methods
- Acid mine discharge treatment methods
- Aircraft or satellite remote pollution/crop damage detection system
- Osmosis filtration systems
- Water and sludge recycling systems

Air Pollution, another long-time problem, has only recently been recognized as such. Public attention is drawn to the visible forms of air pollution: dark outpourings of industrial smokestacks; trails left by jet aircraft, and smog resulting from a combination of pollutants and meteorological conditions. The total spectrum of air pollution is a complex of pollutants from many sources that are irritating and unpleasant, all damaging to some degree.

Particulate pollutant emission from stationary industrial sources in the United States currently amounts to more than 18 million tons per year. Midwest Research Institute predicts that it will exceed 50 million tons annually by the year 2000 if more and better control systems are not applied to the sources. On the other hand, if industry will use control techniques presently available and if some improvement in these techniques is made, the total emission rate by the year 2000 can be lowered to 3 million tons per year.

Photochemical and industrial smog are causing extensive damage to vegetation. In California's San Bernardino National Forest, two-thirds of the conifers, totaling over a million trees, have been damaged by air pollution. In California alone, the economic damage to vegetation has been estimated to be from $8 to $132 million annually. The citrus crop has been reduced 50% by air pollution, primarily a result of ozone and photochemical oxidants from automobile exhaust. An estimated 50% of California's air pollution is attributable to this source.

Power and heat use, primarily generated by burning coal, oil, or gas are sources that are expected to increase air pollution. Resulting pollutants are sulfur dioxide, solid particulates including lead, nitrogen oxides, carbon monoxide, and hydrocarbons and their oxidation products. It is expected that the sulfur dioxide product will double between 1971 and 1990.

The hazards associated with air pollution are having an important effect on health. A recent study of several types of cancer shows significant correlation of this disease with chronic exposure to sulfur dioxide and nitrogen

dioxide. Based on this study, it is estimated that a fivefold reduction of Chicago's average annual sulfur dioxide concentration (with all other variables remaining constant) would reduce the city's cancer deaths by about 800 per year. Health hazards are exemplified by several air pollution catastrophes. One such occurrence in London in 1953 led to more than 4000 "excess deaths." The one recent instance of lethal air pollution occurred in New York City during the Thanksgiving weekend of 1966. Approximately eighty people apparently succumbed to the high levels of sulfur dioxide and other pollutants which accumulated over the city during the weekend.

Air pollution control and abatement are being advanced through the application of new technology. Problem areas requiring introduction of new technologies include development of:

- A new class of advanced pollutant sensor
- Aircraft and satellite remote sensory systems
- Control techniques for various pollutants
- Air pollution models
- Odor detection and control systems
- More efficient combustion processes

Also, needed are new technologies for:

- Analysis of effects of pollution on human physical performance
- Reduction of motor vehicle exhaust
- Improvements in Rankine cycle engines and gas turbines
- Improvements in particulate measurements

Transportation difficulties illustrate the complexities of applying technology to significant areas of public concern. In transportation, as in other public sector areas, technology is interrelated with political, organizational, economic, social, and financial problems. Technological improvements alone cannot solve the major problems in transportation. On the other hand, when roads and parking lots require 40 percent of some cities total land use, and 64 percent of American commuter or work trips are made in private automobiles, generally at very low speeds, technological improvements are obviously needed.

Some problem areas in transportation that need technological assistance, are:

- Systems planning of urban transportation needs
- Investigation of human factors in automobile operation
- Development of improved aircraft noise suppression equipment
- Investigation of crashworthiness of all types of vehicles
- Development of improved traffic network signal timing systems
- Improvements in passenger restraint systems
- Instrumentation for detecting rail stresses
- Improvement in tank car safety in accidents
- Systems for detecting roller bearing failure on rail cars
- Improved pavement striping materials

- Development of nondestructive bridge and highway test techniques
- Better pollution control techniques

The Postal Service has recently begun an extensive technology development program. Its 1971 research and development budget has increased to $65 million and it will grow at a rate of 30% annually through 1975. A significant portion of an estimated $5 billion to be spent between now and 1975 by the Postal Service will purchase more engineered products to automate mail handling. This will include optical character readers and sorters that will process 40,000 addresses per hour. The Letter Mail Code Sort System, LMCSS, now being included in a test-bed installation in Cincinnati represents "the first total change in the concept of mechanization of letter handling in the history of the Post Office" according to Alvin P. Hanes, the program director of letter mail processing in the Postal Service's Bureau of Research and Engineering.

Postal Service needs include development of context analysis software to interpret incomplete address information; development of a standardized system for controlling the conveyerized sorting of nonletter mail; improvement of noise reduction and control methods; and improvement of surveillance systems. Because of the size and labor characteristics of the Postal Service, employing 750,000 people of which only 5000 are supervisory, even small improvements can have tremendous long-term benefits to cost and service efficiency. Last but not least is the need to handle an ever-increasing burden of mail for our expanding population.

OVERVIEW OF NASA TECHNOLOGY

OVERVIEW OF NASA TECHNOLOGY

Technology developed or improved under NASA sponsorship has a potential for secondary applications which has only begun to be tapped. Innovative application of much of this existing technology can drastically reduce the economic or social costs of industrial operations or products; it can greatly simplify or improve products or operations and make them more accessible to the average individual or researcher; or it can provide a wide range of alternative ways of doing things that do not have the same negative side effects as existing procedures. Although the aerospace research and development which fostered this technology is not generally oriented towards providing a direct, short-term benefit to the man in the street, he will both directly and indirectly benefit from the impact that it has had on the use of satellites for communication and earth resources, the computer and electronics industry, the development of biomedical instrumentation, on materials, and even housing.

This sampling of aerospace technologies is an attempt to characterize the scope and depth of technological knowledge, expertise, and equipment serving as the basic resource of the NASA Applications Team Program. The technology regularly used by the Program ranges from pieces of equipment or systems (hardware) to technical knowledge and expertise, computer programs, techniques, materials, and, often, highly creative ideas. The sources of this technology are NASA scientists and engineers, contractor personnel, and NASA-supported university researchers. A description of the NASA Application Teams and the means by which they focus on these knowledge resources is described in the next chapter.

SATELLITES IN COMMUNICATION, WEATHER FORECASTING, GEOGRAPHY, CARTOGRAPHY, AND AGRICULTURE

Satellites have been one of NASA's primary contributions to the improvement of communication, weather forecasting, geography, and agriculture. The application of satellites to such disciplines resulted from extensive scientific and engineering investigations conducted during preparation for the manned Gemini, and later the Apollo Programs.

The communications satellite, used for international television, orbits thousands of miles above the earth. It can afford a living room view of such events as the Olympics in Mexico and France, and the opening of Expo '70 in Japan. Although enjoying widest renown, television is not the primary benefit of the communication satellite. Far more significant gain has come to world commerce through the satellite's ability to provide cheaper and more reliable, long-range communication, and through the ease of contact it provides by virtue of its capacity.

The meteorological satellite has brought many technological, economic, and social returns through weather forecasting by space observation. The satellite is equipped with sensors that respond to such atmospheric conditions as temperature, pressure, moisture, and air movement, and is widely used to identify destructive storms.

The disciplines of geography, land use, and cartography are also aided by data derived from orbital and aircraft sensors. A remote sensing system

built for NASA by Bendix Corporation is currently being flight tested aboard a NASA/Lockheed C130. The system is an experimental multispectral scanner destined for research on remote sensing and the processing of data related to the nation's natural resources. During a recent test flight, the scanner recorded data from a crop of winter wheat that appeared uniformly healthy to the human eye. Multispectral tapes, however, revealed that at least half of the crop, and perhaps more, needed more fertilizer, different drainage, or other action. The data derived from multispectral scanning systems is expected to be used for agricultural inventory and planning, observation of the direction of urban development trends and determination of land use. NASA's continued commitment to an Earth Resources Technology Satellite (ERTS) Program will continue to expand, to improve remote sensing technology, and add to the already solid economic value of the Program.

POWER SOURCES

Fuel Cell Technology. Unmanned vehicles secure their power from the sun through solar cell arrays which provide adequately for their low power usage. The Apollo Program required much higher power levels for the Command Module. Skylab, a space orbiting scientific workshop, will require still higher power levels for the operation of the many scientific experiments, and for life support systems for the men who will live in the orbiting lab for up to 30 days. This power requirement has led to the consideration and development of small isotope or atomic power generation plants. Although these components present safety hazards when they are an integral part of a space station, shielding methods and materials are being developed to meet this need. Development of the small atomic generator or fuel cell may eventually enable each home and building to have its own self-contained power supply and waste processing system. It is interesting to note that the fuel cell delivers a bonus supply of fresh clean water. This might make a new supply of water available to every home, thereby reducing the demands on presently available natural supplies.

MATERIALS

Composite Materials. Composites are materials possessing high strength-to-weight ratios. The most fundamental of these probably are the fiberglass laminates used in power boat hulls and automobile bodies. Advanced aerospace requirements have resulted in entirely new types of composite materials where thousands of "whiskers," or small needles of carbides, are combined with aluminum and other metals during the smelting process. Alloys are thus created for castings and forgings which have greatly improved physical properties. Composites emerging from this research have provided the industrial designer with new materials which allow for greater innovation and flexibility in product design and applications. Other forms of filament composites, used originally in the fabrication of missile bodies and rocket engine nozzles, are already being used in the fabrication of housing modules for innovative urban development projects.

Plastics. Advances have accrued in the field of plastics through improvements in the formulation of high temperature polymers. A polymer called "pyrrone," has the ability to sustain massive radiation doses and represents the best combination of thermal- and radiation-resistant properties of any organic polymers that have been tested. Projected uses of pyrrone foams will be

as lightweight structural materials on subsonic aircraft. It will constitute passenger aisle ways; be used as improved aircraft electrical hookup cable using pyrrone adhesive to give at least 200 degrees F increased performance capability; and comprise laminates that will be relatively light and very rigid for use in the advanced composite engine. Another consideration is a pyrrone binder, used as solid film lubricant with increased temperature capability, for use in gyroscopes and the Apollo telescope mount. Studies have shown that the material can form membranes that are potentially stronger and more efficient than some currently used commercial membranes for such diverse applications as life support systems, desalination of water, and battery separators. In addition, pyrrone moldings and laminates are undergoing evaluation for use in lithium batteries employed as energy sources to help reduce pollution.

A polyamide prepolymer known as P13N should be widely useful in ablators, supersonic aircraft structures, jet engine components, circuit boards, flexible electrical cable insulation, and as a high temperature adhesive. P13N can be molded easily for seals, self-lubricating bearings, valve seats and bushings.

HYSTL is a polymer that is made from a viscous liquid prepolymer that can be readily chain extended to give an elastomeric composition. In this form it can be mixed, molded, or extruded, and gives "prepregs" with excellent drape characteristics. Since the properties of the intermediate elastomer can be varied over a wide range, HYSTL provides manufacturers with more processing flexibility than is available with other thermosetting compositions. HYSTL has aroused interest from a maker of grinding wheels, an electronics manufacturer, a casket-manufacturing company, a firm supplying aircraft and missile components, and a chemical manufacturer.

Solid Lubricants. Improved lubricating materials are constantly being sought in an effort to further reduce the energy loss and component wear caused by friction. With increasing trends toward the use of higher and higher temperatures in moving parts, commonly used petroleum oils have become inadequate and have had to be replaced by new, synthetic materials. With the introduction of supersonic aircraft and spacecraft, temperature and pressure conditions have become even more severe, and the search for more effective lubrication has resulted in the development of solid lubricants. Solid lubricants have the advantage of good stability at extreme temperatures and in chemically reactive environments, and afford the design advantage of lighter weight, simplification, and improved dynamic and mechanical stability--a must in modern aviation and space technology. Solid lubricants show a large market potential for use in the automotive, heavy electrical, metal working, and marine industries. Although solid lubricants will not totally replace the more conventional lubricant, they will open up new frontiers to operating machinery, not only under high temperatures, but also under conditions of extreme cold, very high vacuum, nuclear radiation, and extreme loads.

Inorganic Coatings. Advanced space/missile requirements dictate the development of new combinations of materials with markedly superior properties. The sophisticated combination of two or more substances into a composite-materials system yields a combination of properties unobtainable from either substance alone. A vitreous-porcelain enamel, for instance, combines the strength, flexibility, and other useful properties of the metallic substrate with excellent chemical resistance, diversity of color and texture, and ease

of cleaning. Inorganic coatings represent an important division of composite-materials systems currently undergoing rapid development to serve novel applications. They may comprise materials such as glasses, crystalline ceramics, carbides, silicides, borides, sulfides, and metals. These in turn have application in areas such as thermophototropic coatings for new optical devices, with optical properties which vary in response to light intensity; and thermal control coatings, useful for solar energy conversion systems as well as for thermal control.

Fire Retardant Materials. Constant exposure to propellant materials, such as the very corrosive fluorine and combustion-supporting oxygen, has led NASA to research improved methods for the evaluation, processing, and handling of such material. Associated research has led to the development of noncombustible materials that prevent or extinguish fires. Advanced flame-resistant material could dramatically reduce the number of fires which occur in this country each year. Government agencies, industry, and private organizations are exploring the possibilities of their use across a wide spectrum to include fire fighting equipment, hospitals, building materials, and aircraft.

A case in point is polyurethane foam. When heated, the foam releases gases which inhibit combustion and convection. It also forms a surface char which tolerates high temperatures and reradiates a large fraction of the incident heat. These properties make it an extraordinarily effective thermal insulator for protection in situations where none formerly existed. In aircraft, many of the fatalities occur when people are burned to death by igniting aircraft fuel that burns with an extremely hot flame. In little more than a minute, cabin temperatures can soar hundreds of degrees and virtually reduce to nil the possibility of passenger survival. The foams developed by NASA could well be an answer to the air transportation industry's attempt to deal with this tragic situation. In a test conducted by scientists from Ames Research Center and the AVCO Corporation during the summer of 1970, a C-47 aircraft fuselage was separated into two sections by steel bulkheads and the sections insulated: one with the foam and the other (the control section) with a two-inch blanket of fiberglass batting--the standard insulation used in today's aircraft. The sections were equipped with movie cameras and instruments to measure temperatures and toxic gas concentrations. The fuselage was surrounded with a pool of several thousand gallons of jet fuel and the entire assembly ignited. Within two minutes the temperature in the control section was above 500 degrees F, whereas in the protected section it was slightly above 100 degrees. After ten minutes, a sufficient time for passengers to escape, the heat was still within the human tolerance limit of 275 to 300 degrees. Also significant was the absence of detectable quantities of toxic gases in the protected cabin. Ways in which these foams can be used to insulate military aircraft are now being actively pursued by the air transportation industry.

Another fire retardant material is a durable, easily applied inorganic paint with superior thermal absorption and emittance properties. New uses for this substance include electrical purposes as well as direct application to conventional construction materials, and incidentals such as truck exhaust systems, oven liners, fire walls, ventilating shafts, brake drums, engine manifolds, mufflers, and furnaces.

Beta fiber, a glass fiber of extremely fine diameter, can be woven into textiles while still remaining nonflammable, unusually flexible, pliable, and soft. If coated with Teflon, the material is abrasion resistant and can be made into cloth for protective work clothing. Prototype suits made of this material are to be tested soon by fire departments across the country. Special sheets, pillow cases and patient gowns have already been developed for cancer patients who must be treated in hyperbaric chambers with several atmospheres of oxygen.

Although society's need for fabrics that will not burn, for housing that will not burn, and for vehicles of all types that will not burn may not be realized in the immediate future, there is little question that fire safety work accomplished in the Space Program will play a part in meeting the demand for protection from burn hazards.

BIOINSTRUMENTATION

Electrocardiography is a valuable diagnostic tool that helps the physician detect heart damage or irregularities before they become a serious hazard to his patient's health. NASA requirements for monitoring the astronaut's electrocardiogram waveform resulted in several advances in this field through improved construction, attachment techniques, and development of the dry capacitance electrodes. Flexible electrodes, developed for extended space missions, consist of silicone rubber loaded with conductive metallic particles. The electrodes can be molded, cut to fit comfortably over irregular body contours, and have the additional advantage of moving with the skin. They cause far less irritation than normal electrodes and their comfort makes them especially advisable for use with infants. The spray-on electrode has been important to EKG transmission systems because of its rapid application and reliability even under emergency conditions. Even more useful than the spray-on electrode may be a harness containing six electrodes. It is currently undergoing development and promises to save much time in clinical testing facilities.

Cardiac Output or ventricular stroke volume can now be monitored through a four-electrode impedance plethysmographic system. It has good potential for clinical use and has already been used to monitor heart transplant patients during postoperative periods. The system enables the physician to closely monitor the volume of blood passing through the heart without the need for surgically implanted electrodes or transducers. The importance of the device is that a failing heart can be detected at an early stage by monitoring the stroke volume so that corrective action may be taken before it is too late.

Present techniques for blood volume determination require heart catheterization and hospitalization. An implantable, miniature ultrasonic sonomicrometer, under development at NASA's Ames Research Center, will be used to measure the dimensions, and changes in dimensions, of the left ventricle during the heart beat. The instrument uses the echoes of high-frequency sound waves bounced off the front and rear walls of the heart to electronically determine blood volume ejected from the heart at each beat.

Phonocardiography is the process of obtaining and recording the sounds produced by the heart. It provides information which is different from EKG tests, and presents the physician with additional data for the diagnosis of

cardiac defects. NASA developmental work has produced a microphone with superior frequency response to detect these heart sounds. The microphone is small and readily adaptable to mass production techniques.

The movement of the heart during the cardiac cycle produces accelerations of the chest wall. These accelerations are strongly related to the stages of contraction, ejection, systole, and diastole. Vibrocardiography may produce a record of these accelerations as accurately as the method of cardiac catheterization. The detection of the extremely small accelerations requires a very sensitive transducer whose development NASA has funded. It provides the physician with a highly accurate and detailed vibrocardiogram reading.

In indirect blood pressure measurement, early NASA work involved automating the sphygmomanometer. The automated device has been clinically used and has been found to be more accurate than the standard manual method. A transducer used as a direct force balance probe to detect the force required to restrain arterial deflection is another technique that is, although not perfected, feasible. Another method for rapid venous pressure measurement requires only that a patient exhale fully through a constricted orifice. The exhalation causes the pressure in his lungs and the surrounding area (including the heart) to rise. The pressure measured orally is equal to the venous pressure at heart level. If the oral pressure is sufficiently increased, the blood flow toward the heart in a vein in the arm will cease when the arm is at heart level, and the oral pressure is equal to or greater than the venous pressure. A transcutaneous doppler blood flow sensor is used to detect the instant when the flow ceases. The automated sphygomanometer and the other methods described already are, or will be, of value to the clinician in providing rapid, noninvasive pressure measurement.

Peripheral arterial and venous blood flow. Noninvasive ultrasonic techniques have proven successful in studies to determine blood flow velocity. Such instruments radiate high-frequency sound waves into an artery or vein and detect phase shifts that occur in sound waves reflected off moving blood cells. Two innovations can be noted. The first is a continuous wave doppler flowmeter capable of sensing the direction of the flow. The second is a pulsed doppler ultrasonic flowmeter that detects the direction as well as determines the cross sectional blood flow profile and internal diameter of an artery or vein. Both flowmeters show promise for the future in research and diagnosis of peripheral vascular diseases.

Included in Skylab experiments is the Lower Body Negative Pressure (LBNP) device. It produces controlled reduction in pressure around the lower body to permit evaluation of the reflexes of the cardiovascular system. The reflexes normally serve to regulate regional blood flow, thus affecting the distribution of blood throughout the body. When a person is subjected to a changing gravitational field, the cues to which the reflexes respond change and become eliminated in the absence of gravity. Under induced dynamic load conditions, measurement of the status of the reflexes should give good indication of the cardiovascular system's ability to respond. Cardiovascular measurements made with the LBNP should help to establish the onset, rate or progression, magnitude, and significance of any functional changes in these protective cardiovascular reflex responses. Other cardiovascular system assessments to be recorded during the LBNP stress testing include adjustments of the heart

to loads imposed by the space environment, changes in leg volume due to changes in venous tone in the lower limbs, and changes in blood pressure. Similar induced stress reaction studies performed on clinical patients should help the physician assess the state of his patient's cardiovascular system and allow him to detect defects that he may not normally be able to diagnose.

ANALYTICAL CHEMISTRY TECHNIQUES AND INSTRUMENTATION

A review of NASA contributions to the design, development, and application of instrumentation for analytical chemistry demonstrates the ingenuity of analytical chemists in their effort to detect and to comprehend the nature of substances existing on distant planets without leaving their laboratories. Some of these developments have already been incorporated into commercially available instruments; others, reported by industrial concerns under contract to NASA, will no doubt find use in commercial application; still others will require further development before they can be incorporated in devices suitable for a highly competitive market. Yet, without doubt, the new developments in analytical instrumentation represent definite advances in the technology of analytical chemistry and will prove useful to other chemists.

Refinements in ultraviolet spectroscopy sprang from the necessity of detecting ultraviolet radiation in space for a definitive analysis of stellar and planetary atmospheres. The need for selective and more sensitive methods for detecting ultraviolet radiation has resulted in improved fabrication techniques for photomultiplier tubes and a novel ceramic photoionization-chamber detector which is now commercially available. A vacuum ultraviolet polarizer and analyzer has been used experimentally by NASA for the study of crystal structures. It seems to be adaptable to the examination of solid-state materials and to techniques for the optical pumping of lasers. The ultraviolet density meter may be particularly useful for light testing of aircraft and for use on meteorological sounding rockets. The application of ultraviolet and J-band absorption techniques to the detection of protein constituents in waters and soils (indicative of living organisms) will be of significant value to medical research and for the protection of public health; particularly when it is necessary to detect traces of materials which may promote life or destroy it.

The detection of infrared radiation is as important to the meteorologist as infrared absorption is to the analytical chemist. NASA work in the detection of infrared energy has led to the development of a dielectric bolometer; instrumentation for determining the heat balance of Earth and other planets; and a submillimeter interference spectrometer. Such instrumentation may have direct application to the acquisition of meteorological data from Earth, aircraft, and spacecraft, and may lead to better weather forecasts and better crop management.

Gas chromatography instrumentation applied to space exploration has required modifications to improve the construction and operation of automated models; to increase the reliability of electronic circuitry; and to provide efficient separation of compounds in complex mixtures. Pyrolytic gas-chromatography techniques used by NASA analytical chemists in the detection of microorganisms has generated information which supplements available data obtained with abiogenic materials. These techniques will be of particular interest to laboratories engaged in health and sanitation services and may

prove more rapid than classical procedures of inoculation and incubation for the identification or classification of the lower forms of life.

Neutron-activation analysis facilities are usually complex and expensive. Results of work in NASA programs suggest that a miniaturized neutron-activation instrument will serve a useful purpose in such things as water pollution control and drug and food control where samples can be generous and allowable limits for elemental contaminants are in the parts-per-billion range.

The restrictions of power and volume requirements for space exploration have necessitated the miniaturization of X-ray spectrometers. These instruments are an important class of analytical tool because they provide diagnostic information on the structure of crystals. Portable X-ray spectrometers have been developed for the national space program, but they are destined to be used on Earth by geological and geochemical expeditions to locate minerals of industrial importance.

Life detection. Analytical techniques for the detection of extraterrestrial life utilized many standard analytical instrumentations that required miniaturization and remote operation. The techniques often concentrated on one specific functional determination to yield maximum information.

The Gulliver, a successfully automated device, is based on a technique involving the measurement of the radioactive carbon dioxide released by the metabolism of an isotope-labeled nutrient by extraterrestrial microorganisms. The instrument collects extraterrestrial soil, releases the nutrient to the sample, and measures the resulting labeled carbon dioxide by means of a Geiger counter. The device weighs less than 3 ounces, is a few inches long, and contains the radioactive medium, power supply, heater, and Geiger tube, plus the mechanical devices for programming the sequence.

The Marbac system is based on measurement of the changes in chemical oxidation-reduction potentials caused by the metabolic processes of microbial life. It consists of multiple chambers or cells in which several different nutrients are injected in test cells and control cells. It identifies the various kinds of microorganisms by determining the difference in redox potentials generated by the metabolic reaction in nutrient solutions of differing composition.

The Multivator is a miniaturized and automated system utilizing spectrophotometric techniques that include nephelometry, fluorometry, and calorimetry. The general design of the instrument incorporates modules that contain a reaction chamber, solvent-storage chamber, tapered pin valve, explosive-charge bellows, and filtered light source. In operation, dust (containing microbes) is filtered to eliminated large particles and is blown into the reaction chambers where it is collected on sticky walls; the dust-free "air" is then exhausted through a port. Inlet and outlet ports are closed, and the solvent is injected into the reaction chambers which contain a substrate of dry reagents. After a predetermined time for hydrolytic reaction, fluorescene excitation lamps are turned on sequentially, and the fluorescent level in each chamber is detected by a phototube. Particular attention has been paid to the assay for phosphatase activity since it occurs widely in terrestrial organisms; catalyzes a wide range of reaction with moderate specificity; is involved with

the role of phosphorus in metabolism and energy transfer; and can be detected with high sensitivity.

The Wolf Trap is based on the detection of two effects that microorganisms have on a nutrient solution; change in pH, or acidity of the solution; and change in light transmission, or turbidity of the solution. Change in pH is detected by pH electrodes; change in turbidity is detected by a light scattering technique. The rate of change of pH and turbidity provide information for the interpretation of acquired data. The device picks up dust samples and forces them through a venturi into a nutrient chamber by use of a compressed gas. The instrument can detect turbidity corresponding to 10^7 microorganisms per milliliter and a change of 0.5 units of pH.

Although life-detection techniques in general are not new, new developments in miniaturization and automation, the various approaches, development of media, and exploratory results, are of great interest to bacteriologists, virologists, and biochemists, as well as to laboratories concerned with health and sanitation. For example, a biomedical byproduct of life-detection studies is an automated technique for detecting bacteria in urine. The technique reveals the presence of bacteria within minutes as compared to 24 to 40 hours required for the standard culture technique. The instrument may eventually enable doctors to screen large numbers of patients and positively identify those with urinary tract infections. This procedure should eliminate precautionary administrations of antibiotics if the test is negative.

ENVIRONMENTAL MONITORING

Analytical chemistry instrumentation developed for identifying, measuring, and controlling the atmospheric components of the sealed-spacecraft-cabin atmosphere has been found to be functionally suited to air pollution monitoring on a broader than heretofore possible scale. A small, general purpose, cycloidal-focusing mass spectrometer was originally developed to continuously monitor the respiration of a test pilot for correlation of various respiration products with stress conditions being experienced by the pilot. This mass spectrometer is capable of simultaneously monitoring 12 gases, with molecular weights of 3 to 100 atomic mass units, with a continuous input. The delay time is 300 milliseconds, and the response time is 30 to 50 milliseconds. This compact instrument is 10 by 11 inches and weighs 28 pounds, exclusive of the vacuum system. An instrument built to the specifications of this prototype may be suitable for detection and analysis of most of the gaseous constituents of the atmosphere and its portability gives it added potential for use by environmental monitoring agencies.

Another piece of technology is the trace-gas analysis procedure developed to collect and analyze gases in the Apollo spacecraft cabin. It is suitable for use in air pollution research facilities to monitor special manufacturing processes, or in research work. A third item is a device used to detect glycol vapor in spacecraft cabin atmospheres. This device is suitable for detection and analysis of glycol in the atmosphere at a very low per-sample cost.

Other instruments and techniques usable for air pollution monitoring activities include a hot-wire detector for chemically active materials (once used for cabin-contaminant identification and analysis), and a microwave

spectroscope in which detection of molecules is based on the absorption of various microwave wavelengths by different gases.

The identification and analysis of possible toxic concentrations of gases and vapors within a spacecraft cabin are not the only areas of gas monitoring to which NASA has contributed technology. Other aerospace-developed analytical systems include welding gas monitors, welding spectrometer analyzers, and clean assembly-area monitors. As in the case of cabin-atmosphere monitoring, these techniques, too, have applicability to the monitoring of air pollutants. Finally, measurement of air pollution from satellites is now also feasible through use of such instruments as lasers, infrared sensors, and microwave equipment, and will provide information that will contribute to the detection of contaminants which threaten our environment.

TELEOPERATORS AND HUMAN AUGMENTATION

Because man must work in outer space, ocean depths, and other hazardous environments, either assistance or substitution of man's extremities, and thus his capabilities, is required. Teleoperator technology provides an ability to augment man's hands, arms, and legs with machines. A teleoperator is a general purpose, dexterous, mechanical substitute for man's limbs. This man-machine cooperation enables man to pick up and examine samples of the lunar surface while remaining on earth; to repair an underwater oil pipeline from the surface of a ship; to manipulate radioactive nuclear fuel elements in a "hot" atomic cell; or to lift a ton-sized load--the man amplifier concept. The considerations that help determine when a teleoperator system will be used are man's absolute physical limitations in matters of strength, size, and bodily construction; the need for human welfare or safety; and economic considerations.

Since an astronaut is vulnerable, expensive, and nonexpendable, special purpose remote-control machines have been developed by NASA to perform many manipulative tasks in outer space. Secondary application of these remote-control machines and of teleoperator technology generally is now successfully being accomplished in the prosthetics (artificial limbs) field as engineers apply improved materials, better power supplies, and improved control techniques. In the future, the augmentation and extension of man by teleoperator will enable him to conquer factors of distance, high temperature, high pressures, noxious atmospheres, and other dangerous environments on the periphery of his narrow domain. For example, it may permit remote surgery on a patient a thousand miles away, or it may help marine scientists to mine and cultivate raw material and food supplies now locked deep in the oceans.

COMPUTERS

Microelectronics, Integrated Circuitry, and Third Generation Computers. NASA space research programs have been most active in the development and application of microelectronic devices. These devices encompass technologies by which electronic circuit functions are fabricated in small, solid structures that are both reliable and inexpensive. Microelectronics has been invaluable in such applications as the IMP I satellite's optical aspect computer, the test apparatus that provides ground support equipment for the Apollo guidance computer, and the circuitry of multichannel digital computers. It is now finding widespread commercial application in telephone switching circuits,

television, and small desk-type and other commercial computers. Microelectronic technology has opened entirely new possibilities in electronic instrumentation and data processing that were not feasible with larger electronic components.

Spaceflight checkout requirements to determine the flight status of the major components of rocket booster stages and vehicles, hundreds of subsystems, thousands of assemblies, and hundreds of thousands of individual devices stimulated the development of completely new and unique methods. The time factor required for checkout to meet the very narrow launch constraints is critical, making automated methods essential. Early in its program, NASA required the computer industry to develop machines with greatly expanded memory capacity and significantly faster computational ability in order to use automatic or computer-operated test methods. These requirements made the drum memory unit obsolete and forced the redesign of electronic circuitry. The so-called "Third Generation Computer" was born, with its massive banks of disk and core memories, and integrated circuitry was introduced into computer design. This new machine, probably best identified by the trade name "IBM 360 System," is the system that is revolutionizing accounting, record keeping, banking, technical data banks, and data processing, and has fostered a new industry identified as "Time Sharing." This is a system by which a number of companies with similar requirements for data processing share a remote computer by using input/output consoles. The "Time Sharing" concept has made modern computer technology available to medium size and small businesses, thereby improving their profit potential and competitive position in the market place without necessitating large capital investments in industrial computer equipment.

Image Enhancement. Digital computers have been widely used in the aerospace community to correct various photometric, geometric, and frequency response distortions in the images received from the television cameras of Ranger, Mariner, and Surveyor spacecraft. Two types of processing can be performed by a digital computer on a television image. The first type of processing is content analysis by which the computer extracts information from the image and presents the resultant information nonpictorially, that is, as numerical data. In the second type of processing, image enhancement, the goal is to improve an image so that a human photo-interpreter can more readily find what he is looking for. Image enhancement, or two-dimensional digital filtering, is particularly useful for bringing out fine detail that is often invisible in an unprocessed image. This computerized image enhancement method has proven invaluable in revealing detail that was not previously obtainable in medical and biological photographs. It is being applied to facilitate the interpretation of chest X-rays and retinal images, and is used in light microscopy image enhancement of chromosomes. A closely related application is an optical tracking device used to study blood flow velocity in the capillary blood vessels. Such research is important to an improved understanding of the body's ability to react to or withstand severe environmental stresses.

Insight into the functioning of a human heart can now be gained through a recently devised computer method. It projects a three-dimensional cartoon-like image of any desired chamber of a patient's heart on a computer display screen, similar to the face of the television screen. The display is exact enough to show sections of the heart the size of a nickel; details of large coronary malfunctions; and holes between heart chambers. The computer system,

still being developed, will allow doctors to watch a "movie" of a disease patient's beating heart. Details are clear enough so that doctors can identify scar tissue, aneurysms, or other faults. The picture can be projected over and over again, allowing study of the heart in action for any desired period of time. Since the animated displays are a form of computer readout, they may eventually be transmitted to doctors at distant locations by a telephone line and recreated on a console display screen. From a medical viewpoint, the system is seen as a potential major advance for determining whether a patient needs heart surgery, arterial grafts, or other treatment.

CLEANROOM TECHNOLOGY

Strict contaminant control during the manufacture of spacecraft components is imperative. The function of a propellant system valve in an attitude control device could be impaired by minute airborne particles causing loss of both spacecraft and life as well as a large economic investment. Two design concepts for cleanrooms are in current use: an older type, referred to as a conventional flow cleanroom, and a more advanced design using the laminar flow principle. Interest in incorporating the laminar airflow principle into hospital construction has been widely expressed.

Aside from medical applications, cleanroom technology is important in the manufacture of electronic components--items such as miniature valves and ball-bearing assemblies; in tube welding; and in the performance of work on high precision instruments such as watches and relays. Reliability and quality assurance in manufacturing has important economic significance. Air Force experience in equipment maintenance over a five-year period demonstrated that prior to the use of cleanrooms, maintenance costs were ten times the initial cost of the equipment utilized. At any given time, from 65 to 75 percent of the equipment was inoperative. On the other hand, with cleanroom technology utilized both in manufacture and repair, 92 to 95 percent reliability is commonplace. Cleanroom technology not only reduced maintenance costs, but also enabled the equipment to more nearly fulfill the purpose for which it was designed and built.

PORTABLE LIFE SUPPORT SYSTEM

The challenges of the lunar environment, as well as extravehicular activity, required pressure maintenance and oxygen supply for the astronauts. Space program research in intra and extravehicular operations has advanced technology in the following areas: oxygen supply and pressurization; carbon dioxide contaminant control; thermal and humidity control; power; communications--voice and telemetry channel; and instrumentation controls and status displays. Subsequent development of life support systems include the Portable Environmental Control System (PECS); the NASA aircrew oxygen system; fluidic temperature control for liquid-cooled space suits; a heat rejection system for the extravehicular astronaut; research on sodium chlorate candles for the storage and supply of oxygen; and regenerable sorbers. Advanced life support technology from these systems is expected to contribute to improved life support systems for use by miners and firemen.

NONDESTRUCTIVE TESTING

Quality assurance of hardware produced for the aerospace industry is as vital as the observation of contaminant control. A faulty weld could lead to

the rupture of a space vehicle component resulting in costly delays, and, if not discovered, cause the foundering of an entire space mission. Therefore, it is very important to achieve complete assurance of hardware integrity through nondestructive testing (NDT) methods. New ultrasonic transducer designs now permit the inspection of material immediately beneath the instrument (an area of inspection previously lost due to near field effects) and discontinuities in materials undetectable a few years ago, can now be discovered and resolved. Although there still is need for further improvement, continuing advancements in physics and engineering are significantly adding to the NDT state-of-the-art.

Some examples of nondestructive testing techniques used in the aerospace field include: laminography and mutual coupling for the inspection of circuit boards; water-coupled impedance, contact impedance, and the eddy-sonic techniques for the assurance of complete bonding in composite materials; ultrasonic methods for measuring surface stresses in aluminum, and for strength evaluation of bonded materials; and radiographic examinations of electronic components. These techniques are slowly filtering through to the public sector, keeping pace with demands of industry and government. Already such aerospace-developed methods are contributing to the construction of safer aircraft, automobiles, bridges, and other structures.

In addition to comprehensive methods of quality assurance testing, individual devices are also under consideration for utilization by segments of the local and federal government. A NASA-developed fiber optics probe, designed to detect flaws on the surface of rocket tube flares, is currently being tested by the Chicago Police Department as a possible criminalistics aid. On the state level, the Pennsylvania Highway Department is evaluating the feasibility of an eddy-current metal detector as a means of determining the thickness of newly poured concrete.

In response to the often critical time element in nondestructive testing of aerospace hardware, equipment has been miniaturized. The resulting compactness permits several complementary testing methods to be grouped into an integrated system, shortening the total time required for quality assurance, and permitting adequate inspection of the part. Thus, the manufacturing, repair, and damage assessment of materials and structures in the space and lunar environment has demanded and will continue to demand the development of a whole new family of nondestructive test instruments and procedures, whose application in all sectors has an unlimited future.

WATER RECOVERY AND SOLID WASTE PROCESSING

The need for adequate water supplies and sanitation facilities in spacecraft led to the design of an Integrated Water/Waste Management System. The system reuses waste water and hence will not draw on dwindling water resources. Plans are underway to adapt this system to domestic water management and waste processing. A two-phase program will initially formulate its preliminary design for a single family dwelling, and then design, develop, manufacture, and demonstrate a prototype unit.

The program will emphasize utilization of available low water consumption devices that are largely the outgrowth of Space Station prototype development. The concept of a zero gravity whole body shower with low water usage

showering equipment is expected to be adaptable to home use. It involves filtration cleanup and recycling of shower water during the actual operation, with subsequent phase-change reprocessing of the water used after each shower. A zero gravity clothes washer should provide a basis for the development of a low water usage washing machine. Design information will shortly be available that will demonstrate the feasibility of a washing technique using fluidic principles rather than mechanical methods to induce agitation.

Consideration will be given to the practicality of installing the water management and waste processing system in existing dwellings as well as in new construction. The projected impact of wide scale utilization of the system on the available water resources, municipal water supply, and sewage facilities, will then be explored and summarized. Although the reuse of waste water is not yet accepted from the standpoint of aesthetics, diminishing water resources will place increasing demands on the development of waste recycling technology.

AEROSPACE MANAGEMENT TECHNIQUES

The interdependent network of NASA, industry, and university capabilities called upon to deal with the severely complex and sophisticated space effort--whose completion within a predetermined time span was critical--necessitated the use of very flexible, creative, and goal oriented management techniques. Aerospace and NASA managements adapted and often developed a wide range of advanced management capabilities for use within the rapidly changing nature of aerospace missions. The systems environment of the aerospace industry required that its advanced management techniques span many of the more traditional management functions. Many of these techniques have found application in industrial and public sector management. Many others hold promise for future applications as the science of management further diffuses into our societal structure.

Among these advanced management concepts are Program and Policy Analysis, Technological Planning, Organization and Administrative Planning and Control.

The definition of program goals, the identification of alternate approaches, the choice of the most effective projects, and the possible prediction of end results are processes which management must undertake under severe time, information, and resource constraints. In the area of program and policy analysis, aerospace management has made extensive and creative use of techniques such as systems analysis, cost effectiveness analysis, decision analysis (operations research), the heuristics concept, and simulation and modeling techniques. These are powerful analytic tools which assist the manager in defining and making choices among policies or programs competing for scarce resources.

NASA programs such as Apollo have been so large and complex that the systems approach to their management was not only desirable, but necessary. Systems analysis technology can be illustrated as a spectrum of techniques related to each other by several common characteristics which describe the approach taken to problem solving--specifically, a systematic and usually quantitative approach which concentrates on the system as a whole, as opposed to its constituent elements. Techniques which comprise this new technology include operations research, operations analysis, cost-benefit analysis, and

engineering-economic analysis. Since the common characteristics of systems technology focus on the type of approach to problems involved, this systems management approach can be used to attack large classes of problems in many disparate areas. The value of this approach is aptly illustrated by the use of systems analysis in the planning a a $100 million hospital complex in Alberta, Canada, in which officials estimated that the study saved $6 million in brick and mortar costs alone, and it was anticipated that increased staff efficiency, by virtue of optimum design, would save another $12 to $14 million.

The ever growing technological base makes the identification of technological opportunities a function crucial to today's industrial sector. More recently, this task has become significant to many levels of R&D management in the public sector as technology has become recognized as having great impact in the transformation of society and government. Technological planning techniques used in aerospace cover a wide span of subcategories such as technology forecasting, systems engineering management, and value engineering methodologies. Technological forecasting is used to probabilistically identify future technological alternatives. Systems engineering management is an iterative process directed towards definition, design, and evaluation of a functional system. Systems engineering includes methodologies such as reliability analysis and maintainability analysis. Finally, value engineering is a rigorous method to improve the value and cost-effectiveness of a product.

The organizational concepts of program management and project management have enjoyed widespread application in aerospace and other industries. Basically, they permit flexible and detailed control of complex projects under often severe constraints. Program management enables the systematic definition of problems that block the accomplishment of objectives and define in detail the task to be done. It provides for detailed specification for what has to be done, why, when, where, and by whom. Project management techniques are a powerful tool for organizing effective project completion. Matrix organization, for example, permits flexible project management by allowing project managers to integrate and utilize interdisciplinary resources from functional organization elements to achieve an end goal. Other innovative organizational structures such as treaty consortium (INTELSAT) and federal contract research centers (JPL, Bellcom) show promise for solving problems faced by public administrators at local, regional, and federal levels.

The Space Program has demonstrated the feasibility of contracting for sophisticated goods and services on a large scale. NASA carried out this adminstrative planning and control function by leasing a small headquarters staff to procure goods and services from others. To do this effectively, techniques such as the source evaluation board process (SEB), incentive contracting, and contractor performance evaluation are extensively applied. The SEB techniques are used to ensure a sound basis for contractor selection based on price, performance, and schedule criteria. Incentive contracting makes the buyer and seller cost-conscious, communicates the buyer's objectives, and provides positive motivation to contractors. Performance evaluation techniques are tools which measure technical, cost, and schedule progress during a contract's life.

Other planning and control techniques include management information systems, project scheduling/status methods configuration management, logistics management, and quality assurance.

Integrated management information centers, such as the one at Kennedy Space Flight Center, use a variety of data display techniques and capabilities to provide a particular project management group with a unique management device. These centers provide access to and display all information relevant to a project management decision-maker's task. The concept has been adopted for use by city personnel involved in the construction of a new airport, and in the management of other public works construction projects.

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Having reviewed some of society's needs and the scope of aerospace R&D, it is appropriate to understand the NASA Technology Application Program. The next section describes this Program and how it facilitates the beneficial application of aerospace technology and expertise.

NASA'S RESPONSE TO THE NEED FOR TECHNOLOGY: AN ACTIVE PROGRAM FACILITATING TECHNOLOGY APPLICATIONS

NASA'S RESPONSE TO THE NEED FOR TECHNOLOGY: AN ACTIVE PROGRAM FACILITATING TECHNOLOGY APPLICATIONS

The National Aeronautics and Space Administration has generated a vast amount of scientific and technological knowledge in a great variety of disciplines and fields. Recognition of the need to maximize the utilization of this knowledge led the Congress, as stipulated in the original Space Act of 1958, to call for ". . . long-range studies of the potential benefits to be gained from, and the problems involved in, the utilization of aeronautical and space activities for peaceful and scientific purposes." The Congress charged NASA specifically with the obligation to ". . . provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

OBJECTIVES OF THE TECHNOLOGY UTILIZATION PROGRAM

To assist in carrying out that obligation the NASA Technology Utilization Program was initiated in 1962. The stated objectives of NASA's Technology Utilization Program are:

> To increase the return of the national investment in aerospace research and development by encouraging additional uses of the knowledge gained in those programs.
>
> To shorten the time gap between the discovery of new knowledge and its effective use in the marketplace.
>
> To aid the movement of new knowledge across industry, disciplinary, and regional boundaries.
>
> To contribute to the knowledge of better means of transferring new knowledge from its points of origin to its points of potential use.

In order to achieve the objectives set forth, a two-pronged approach to the problem of technology transfer was established. The Scientific and Technical Information Office was formed to acquire, publish, and disseminate aerospace information and was charged with the responsibility to work according to, as well as to improve, the traditional information dissemination mode. In addition, the Technology Utilization Office was formed to institute new approaches to all of the facets of the technology application process, namely the identification, evaluation, publication and dissemination functions of an active technology utilization program.

THE TECHNOLOGY UTILIZATION OFFICE

The Technology Utilization Office's approach for increasing the uses of aerospace technology, for purposes other than aerospace, has been to establish a series of experimental programs. These programs were designed to explore various approaches toward rapid and effective communication of new knowledge to different potential users. The various programs now sponsored by the Office are conducted in technology identification, acquisition, and evaluation phases and the technology application phase.

Most of the technology utilization research effort in the input phase has been directed toward improved methods of identifying and acquiring new technology from the research and development efforts of NASA scientists and contractors. The program provides for a Technology Utilization Officer at each NASA research installation throughout the country. The Officer is responsible for ensuring that contractors connected with that installation document and report (separately from their technical reports) any inventions, improvements, or other forms of new technology developed.

A number of experimental programs are also underway in the output phase, with continuing emphasis on communication with, rather than dissemination to, the potential user. A means of communicating with the user, ongoing since 1963, has been the NASA Tech Brief program. A one- or two-page announcement, the Tech Brief, concisely describes discrete items of new NASA technology and indicates how detailed technical support information can be obtained.

The acceleration of technology flow from developer to user required an intermediary party or "coupler" to coordinate communication between the technology source and receptor. The Regional Dissemination Center (RDC) program utilizes this "coupler" concept. It is a network of university-based and geographically dispersed computerized information storage and retrieval centers. The aerospace data bank, which is stored on computer tapes by the NASA Scientific and Technical Information Office, is made available to the RDC's in the form of computer tapes and copies of individual documents. Qualified RDC personnel acting as "couplers" search the computer tapes for appropriate aerospace technology in response to specific requests and provide a specialized package of information applicable to the problem of the requester.

The Application Team Program is another challenging and innovative program instituted by the NASA Technology Utilization Office to accelerate the transfer of aerospace technology to the nonaerospace user through refined use of the "coupler" mechanism. This report focuses on the recent achievements of the Application Team Program.

THE APPLICATION TEAM PROGRAM

NASA was aware of many efforts at implementing concepts of technology utilization which were passive in nature, that is, information (or technology) is provided to those who are able to seek it. The Application Team Program pursues an active rather than a passive effort, and carries the "coupler" concept one step further. Both problems and solutions are actively sought by the coupler mechanism, in this case, the Application Team.

The Application Team experiment, as originally conceived in 1965, was intended to involve a core of Technology Application Teams located at various research institutes and staffed by professionals from a variety of disciplines. These teams were to meet with investigators to define their problems and to try to locate potential solutions by searching the NASA information system. The teams would, therefore, provide an interface between a problem from one research area and a potential solution from a quite different research area. The research area studied initially was biomedicine and the original Biomedical Application Team experiment tested and verified these hypotheses:

Biomedical researchers are receptive to new technology and would adapt it if it were available and within their resources.

The flow of aerospace technology to applications in biomedicine can be accelerated.

A multidisciplinary interface between the NASA aerospace data bank and biomedicine, using a systematic experimental methodology to identify and relate technical needs with potentially applicable aerospace technology, offers an effective means for translating this singularly oriented mission information to a new mission area such as biomedicine.

The initial success of Biomedical Application Team activity and increased public interest in potential use of aerospace technology to solve other pressing social problems led to an expansion of the Application Team Program. The Program, in addition, now focuses on such public problem areas as air pollution, water pollution, criminalistics and law enforcement, urban construction, transportation, and mine safety.

The Biomedical Application Teams currently have 77 institutions actively participating in the program, which are listed in Table 1. The public sector Technology Application Teams have 103 actively participating institutions as listed in Table 2. A significant achievement and advantage of the Application Team concept is that it gained widespread acceptance in professional communities which are often described as being reluctant to accept and utilize new technology. Organizations developing programs to assist the cities in the solution of their problems have also shown enthusiasm in their participation in the NASA program. The relatively short history of the NASA Application Teams has clearly demonstrated that traditional communications barriers can indeed be bridged when well focused and directed efforts are made to solve pressing problems of our society.

The objectives of the NASA Application Teams are:

To identify significant public problems and needs existing in the problem areas studied which appear to be "solvable" by application of aerospace technology.

To seek out and identify specific aerospace technologies or concepts which may lead to solution of these problems.

To assist problem originators, as appropriate, in the application of these techniques to their problems.

To document successful application of aerospace related technology by researchers as a result of their participation in the Application Team Program.

A key characteristic of the Application Team Program, as noted previously, is that by definition it is participative. Participation or involvement is considered essential to successfully gain user acceptance and transfer

TABLE 1

INSTITUTIONS CURRENTLY PARTICIPATING IN THE BIOMEDICAL APPLICATION PROGRAM

Baylor University Medical School, Houston, Texas
Bowman Gray School of Medicine, Wake Forest University, Winston-Salem, North Carolina
Brooke General Hospital, Fort Sam Houston, Texas
Callier Hearing and Speech Center, Dallas, Texas
Caruth Memorial Rehabilitation Center, Dallas, Texas
Children's Convalescent Hospital, Oklahoma City, Oklahoma
Children's Hospital of Los Angeles, California
Claremont Colleges, Claremont, California
Community Mental Health Services, San Diego, California
Creighton University School of Medicine, Omaha, Nebraska
Doheny Eye Foundation, Los Angeles, California
Duke Department of Community Health, Durham, North Carolina
Duke University Medical Center, Durham, North Carolina
Emory University, Atlanta, Georgia
Fitzsimons General Hospital, Denver, Colorado
General Rose Hospital, Denver, Colorado
Hollywood Presbyterian Center, Los Angeles, California
Hot Springs Rehabilitation Center, Little Rock, Arkansas
Huntington Memorial Hospital, Pasadena, California
Indiana Methodist Hospital, Indianapolis, Indiana
Institute of Rehabilitation Medicine, New York University, New York, N.Y.
Kansas City Health Department, Kansas City, Missouri
Loma Linda University Medical Center, Loma Linda, California
Medical University of Southern Carolina, Charleston, North Carolina
Mercy Hospital of Birmingham, Alabama
Midwest Research Institute, Kansas City, Missouri
Milwaukee County General Hospital, Milwaukee, Wisconsin
National Cancer Institute, Bethesda, Maryland
National Environmental Health Sciences Center, Research Triangle Park, North Carolina
National Heart and Lung Institute, Bethesda, Maryland
Ochsner Clinic and Foundation, New Orleans, Louisiana
Parsons State Hospital and Training Center, Parsons, Kansas
Rancho Los Amigos Hospital, Downey, California
Rosewood Rehabilitation Center, Houston, Texas
Scott and White Clinic and Hospital, Temple, Texas
Southern Research Support Center, Arkansas
St. Joseph's Hospital, Phoenix, Arizona
St. Luke's Hospital, Kansas City, Missouri
Texas A&M University, College Station, Texas
Texas Children's Hospital, Houston, Texas
Texas Institute for Rehabilitation and Research, Houston, Texas
Texas Rehabilitation Commission, Austin, Texas
Tulane University Medical School, New Orleans, Louisiana
United Cerebral Palsy Association, Greater Kansas City
University of Alabama Medical School, Birmingham, Alabama
University of Arizona Medical School, Tucson, Arizona
University of Florida Medical School, Gainesville, Florida

TABLE 1 (Concluded)

University of Iowa School of Medicine, Iowa City, Iowa
University of Kansas Medical Center, Kansas City, Kansas
University of Minnesota Medical School, Minneapolis, Minnesota
University of Missouri School of Medicine, Columbia, Missouri
University of Missouri Dental School, Kansas City, Missouri
University of North Carolina Medical School, Chapel Hill, North Carolina
University of Southern California Medical School, Los Angeles, California
University of Texas Medical School, San Antonio, Texas
University of Texas Medical Branch, Galveston, Texas
University of Texas Southwestern Medical School, Dallas, Texas
University of Utah Medical School, Salt Lake City, Utah
University of Washington Medical School, Seattle, Washington
University of Wisconsin Medical School, Madison, Wisconsin
Veterans Administration Hospital, Albuquerque, New Mexico
Veterans Administration Hospital, Bay Pines, Florida
Veterans Administration Hospital, Birmingham, Alabama
Veterans Administration Hospital, Dallas, Texas
Veterans Administration Hospital, Denver, Colorado
Veterans Administration Hospital, Gainesville, Florida
Veterans Administration Hospital, Jacksonville, Florida
Veterans Administration Hospital, Long Beach, California
Veterans Administration Hospital, Memphis, Tennessee
Veterans Administration Hospital, Miami, Florida
Veterans Administration Hospital, Oklahoma City, Oklahoma
Veterans Administration Hospital, Sepulveda, California
Veterans Administration Regional Office, San Antonio, Texas
Washington University School of Medicine, St. Louis, Missouri
Western Missouri Mental Hospital, Kansas City, Missouri
Western Research Support Center, Sepulveda, California
Woodrow Wilson Rehabilitation Center, Fishersville, Virginia

TABLE 2

INSTITUTIONS CURRENTLY PARTICIPATING IN THE TECHNOLOGY APPLICATION PROGRAM

Air Pollution

Air Pollution Control Office, Environmental Protection Agency, Research Triangle Park, North Carolina

Law Enforcement and Criminalistics

Alameda County Sheriff's Office, Pleasanton, California
Alaska Medical Laboratories, Anchorage, Alaska
American Academy of Forensic Sciences, Pittsburgh, Pennsylvania
Boston Police Department, Boston, Massachusetts
California Medical Facility, Department of Corrections, Vacaville, California
California State College, Long Beach, California
California State College, Los Angeles, California
Chicago Fire Department, Chicago, Illinois
Chicago Police Department, Chicago, Illinois
Cleveland Police Department, Cleveland, Ohio
Contra Costa County, Office of the Sheriff-Coroner, Martinez, California
Criminal Identification and Investigation Bureau, Sacramento, California
Dade County Public Safety Department, Miami, Florida
Detroit Police Department, Detroit, Michigan
District of Columbia Police Department, Washington, D.C.
Florida Department of Law Enforcement, Tallahassee, Florida
Illinois State Crime Laboratory, Joliet, Illinois
International Association of Chiefs of Police, Washington, D.C.
John Jay College, New York, N.Y.
Kern County Sheriff Office Laboratory, Bakersville, California
Law Enforcement Systems Administration, Department of Justice, Washington, D.C.
Long Beach Police Department, Crime Laboratory, Long Beach, California
Los Angeles County, Department of the Chief Medical Examiner-Coroner, Los Angeles, California
Los Angeles County Sheriff's Office, Los Angeles, California
Los Angeles Fire Department, Los Angeles, California
Los Angeles Police Department, Scientific Investigations Division, Los Angeles, California
Marin County Sheriff's Office, San Rafael, California
Maryland State Department of Public Safety, Maryland State Police, Annapolis, Maryland
New York City Fire Department, New York, N.Y.
New York Police Department, New York, N.Y.
New York State Identification and Intelligence System, Albany, New York
Oakland Police Department, Criminalistics Section, Oakland, California
Orange County Coroner's Office, Orange, California
Orange County Sheriff's Office, Santa Ana, California
Pennsylvania State Police, Harrisburg, Pennsylvania
Phoenix Police Department, Phoenix, Arizona
Riverside County Sheriff's Office, Riverside, California

TABLE 2 (Cont'd)

Law Enforcement and Criminalistics (Cont'd)

Sacramento County Coroner's Office, Sacramento, California
Sacramento County, Office of the District Attorney, Sacramento, California
Sacramento State College, Sacramento, California
San Bernardino County Sheriff's Office, San Bernardino, California
San Diego Police Department, Miami Valley Regional Crime Laboratory, Dayton, Ohio
San Mateo County Sheriff's Office, Redwood City, California
Santa Clara County, Laboratory of Criminalistics, San Jose, California
Walter Reed Army Institute of Research, Washington, D.C.

Mine Safety

Bituminous Coal Association, Washington, D.C.
Bureau of Reclamation, Denver, Colorado
United Mine Workers, Washington, D.C.
U.S. Bureau of Mines Research Laboratories at Denver, Colorado; Washington, D.C.; Pittsburgh, Pennsylvania; Bruceton, Pennsylvania

Transportation

American Association of Railroads, Washington, D.C. and Chicago, Illinois
Bay Area Rapid Transit System (BART), San Francisco, California
California Division of Bay Toll Crossings, San Francisco, California
California Division of Highways, Sacramento, California
California Driver Education Association, San Francisco, California
Center for Urban Regionalism, Kent, Ohio
Fairbank Highway Research Station, Washington, D.C.
Federal Highway Administration, Washington, D.C.
Federal Railroad Administration, Washington, D.C.
Highway Research Board, Washington, D.C.
Highway Safety Research Center, Chapel Hill, North Carolina
Highway Safety Research Institute, Ann Arbor, Michigan
Institute of Traffic and Transportation Engineering, Richmond, California; Los Angeles, California
Montana Highway Commission, Helena, Montana
National Highway Traffic Safety Administration, Washington, D.C.
Ohio Highway Transportation Research Center, East Liberty, Ohio
Pennsylvania Department of Transportation, Harrisburg, Pennsylvania
San Jose Department of Public Works and Traffic Engineering, San Jose, California
Southern California Rapid Transit District, Los Angeles, California
Southern Pacific Railroad, San Francisco, California
Transportation Systems Center, Cambridge, Massachusetts
Urban Mass Transit Administration, Washington, D.C.
U.S. Department of Transportation, Washington, D.C.
Washington State, Department of Highways, Olympia, Washington

TABLE 2 (Concluded)

Urban Development

American Iron and Steel Institute, New York, N.Y.
AVCO Corporation, Lowell, Massachusetts
Ball Brothers Research Corporation, Munsey, Indiana
Branson Sonic Power, Dunbury, Connecticut
Building Research Advisory Board of the National Academy of Science, Washington, D.C.
General Services Administration, Washington, D.C.
International City Management Association, Washington, D.C.
Martin Marietta Corporation, Denver, Colorado
Material Systems Corporation, Escondido, California
National Bureau of Standards, Gaithersburg, Maryland
New York Port Authority, New York, N.Y.
New York State Urban Development Corporation, New York, N.Y.
Stanley Works, New Britain, Connecticut
TRW Incorporated, Long Beach, California
U.S. Department of Agriculture/Forest Services, Washington, D.C.
U.S. Postal Service, Washington, D.C.

Water Pollution

American Petroleum Institute, New York, N.Y.
Brigham Young University, Provo, Utah
Bureau of Reclamation, Denver, Colorado
City of Omaha, Water Sanitation Department, Omaha, Nebraska
Dallas Water Utilities, Dallas, Texas
Environmental Protection Administration Agencies at Cincinnati, Ohio; Corvallis, Oregon; Ada, Oklahoma; Athens, Georgia; Duluth, Minnesota
Esso Research and Development Laboratory, Forham, New Jersey
Illinois Department of Health, Division of Sanitary Engineering, Springfield, Illinois
Metropolitan Sanitary District of Greater Chicago, Illinois
Soap and Detergent Association, New York, N.Y.
Standard Oil Company, Chicago, Illinois
University of California, Davis, California
U.S. Geological Survey, Washington, D.C.

technology from one discipline to another. One Biomedical Application Team director noted:

> "Personal interaction is vital when two diverse disciplines are attempting to interact. In fact, disciplines do not interact, but people do. The interaction between two diverse disciplines really results when two people sit down to talk. If we simply give a physician an engineering document, the results are usually zero. The physician cannot begin to realize the significance of modern communications technology to his method of dispensing health care, and the engineer cannot recognize the significance of his cryogenic technology to leukemia therapy until face-to-face and repeated personal interaction occurs. Personal interaction between all elements of the team program (physician, team member, and aerospace engineer) has been found to be of major importance for success."

The brief description of Application Team Methodology which follows underscores the continuous involvement of the researcher with a problem in every phase of the team effort.

METHODOLOGY

The Application Team Program, as an experimental effort, requires constant review and modification of program methodology in order to take advantage of knowledge gained. The four general phases of the program's methodology have, however, remained essentially unchanged. They are: problem identification, definition and acceptance; search for applicable aerospace technology; evaluation and application of the technology; and documentation of the application.

Problem Identification, Definition, and Acceptance. Introduction to the Application Team Program is made through a formal presentation delivered by a team member. However, informal discussions with colleagues already participating in the program may interest the nonparticipant. The prospective Problem Originator then arranges a conference with an Application Team member, where the technological problems of the prospective Problem Originator are discussed in detail. In the next step, the Team member defines the problems in concise terminology of the physical sciences and conducts a preliminary evaluation of each proposed problem.

The preliminary evaluation includes a review of team in-house technology files to serve as pertinent background information. The technology files are composed of commercial product data, NASA publications, and historical data on previously accepted problems, potential applications, and applications. After the background information is reviewed, each proposed problem is screened against broad acceptance criteria. These criteria vary somewhat among the Application Teams, but generally, the factors considered are:

VALUE - Solution to the problem should significantly contribute to progress towards overcoming a major problem identified by the profession served.

SPECIFICITY - The problem should be sufficiently discrete to facilitate formation of specific search strategy.

SOLVABILITY - The problem should appear reasonably amenable to solution by aerospace technology or expertise.

A proposed problem would rarely be accepted for study if it appeared readily solvable, either by known commercially available technology or by knowledge gained from a similar problem, previously solved through Technology Application Team Program efforts. In both cases, the proposed problem would be rejected and the prospective Problem Originator informed of the available technology. (The Problem Originator is always informed of the reasoning behind rejection of his proposed problem.)

When a problem is formally accepted, the Team member prepares a Preliminary Problem Statement which summarizes what is known of the problem at the time, and serves as a means of "gathering thoughts" on the problem prior to search initiation.

Search for Appropriate Aerospace Technology. A preliminary search is based on the initial definition of the accepted problem, augmented by assistance from qualified search personnel at the Regional Dissemination Center (RDC) that supports the designated Team. A Team member then constructs a comprehensive search strategy and the NASA aerospace data bank is searched for appropriate technology.

The problem of retrieving relevant documents for a nonaerospace user is difficult. To accomplish this task one must devise a computer search strategy which will pair subject groups. If only one subject group were used the computer would retrieve more documents than could be economically screened and processed. Use of a second grouping will eliminate many of the extraneous documents. For example, if the problem involved blood flow rate measurement, the search strategy would be constructed to locate all information of technology developed by NASA to measure the blood flow rate and other physiological parameters of astronauts in outer space. The broad groupings used might be medical; sound; flow; and signal analysis.

Pairing of the groups as discussed above will not always recover all relevant documents in the data bank. Many documents will be indexed only under an aerospace term describing the aerospace problem or objective for which the technology was developed. It then becomes necessary for the strategy designer to determine what these aerospace problems or objectives were. Using the blood flow rate measurement as an example again, it would be necessary to develop the search strategy to recover aerospace related information indexed under aerospace terms. For example, technology developed to measure liquid fuel flow rate through flexible tubing in spacecraft might be applicable. Recovery of documents related to this aerospace problem would enable the search strategist to determine the keywords used in indexing that document. These keywords could then be used in further developing the search for aerospace technology relevant to the nonaerospace problem. The end product would be aerospace technology developed to solve a problem quite different from the blood flow rate measurement problem but yet broadly related in a technical engineering sense.

Searching for aerospace technology also involves another approach, that of the active participation of NASA scientists and engineers. To obtain such participation, the Team member prepares a formal Problem Statement which includes a definition and detailed description of the problem, inadequacies of currently available technology, constraints and restrictions on potential solutions, and impact of potential solution. The Problem Statement is prepared in nondisciplinary technical terminology, and reviewed by the Technology Utilization Office prior to dissemination by the NASA Technology Utilization Officers at the NASA field centers, who in turn distribute them to appropriate participating NASA scientific and technical personnel.

NASA personnel, having reviewed the Problem Statement, may be aware of a potential solution. They respond by contacting the Application Team member through the installation's Technology Utilization Officer. A description of the potential solution is forwarded to the Team through the Technology Utilization Officer.

The aerospace data bank search and the Problem Statement distribution provide for identification of most of the reported and unreported NASA technology. Thus, these are the most widely used methods of Teams searching for particular technology. Other means of accessing information on NASA technology are being explored by the Teams, such as visits to NASA field centers, and conferences between Problem Originators and NASA scientific personnel.

Evaluation and Application of the Technology. The Application Team member evaluates the information on available aerospace technology after receiving the results of the RDC computer search, responses to Problem Statements, or any other pertinent information from other sources. He makes a preliminary determination as to whether the identified technology might provide a solution to the problem under study. The extent of this Team member evaluation varies from Team to Team, depending on the particular problem under study, the Team member's relationship with the Problem Originator as well as his needs and objectives.

RDC search results are processed by sending abstracts of technical documents considered applicable to the Team member; he reviews the abstracts, marking those that seem relevant to the problem. These are transmitted to the Problem Originator for evaluation. The same procedure is followed for evaluation of responses to Problem Statements. The Team member rarely fails to identify at least some applicable technology in the computer search results or the Problem Statement reponses. Irrelevant information, as a rule, is not passed along to the Problem Originator. Instead, the Team member reevaluates the problem. The reevaluation forms the basis for redefining the search criteria or for closing out the problem.

When the Problem Originator receives the results of the Team search activities, he also evaluates the information. If his evaluation indicates no potential apparent solutions, the Problem Originator notifies the Team member, and a second evaluation of the problem is made.

If a potential solution to the problem is found, the problem is then known as a Potential Application. During the time between Potential Application and Application the Team member and the Problem Originator work together

closely to bring the Application to fruition. This involved interaction includes such activities as locating NASA hardware for loan and/or development, developing of design specifications for fabrication, obtaining funding or other means to modify or fabricate, and arranging for test experiments. These steps cause the time required to bring a Potential Application to the Application stage to vary considerably, depending on the problem.

Application Documentation. The Team member has the responsibility of preparing an Application Report after fabrication and testing, and successful application of the technology to the problem. This completely documents both the process and impact of successful application of aerospace technology. A flow chart of the basic Application Team methodology is shown in Figure 1.

CURRENT PROGRAM ELEMENTS

There are eight NASA-funded Application Teams currently in the program. Three are the original Biomedical Application Teams (BAT), located at Midwest Research Institute (MRI), Research Triangle Institute (RTI), and Southwest Research Institute (SwRI). A fourth Biomedical Team was recently established at the Stanford University Medical School.

Three other Application Teams also located at research institutes are designated Technology Application Teams (TAT), since they function to study public sector problems other than biomedical. Their locations are: IIT Research Institute (IITRI), Research Triangle Institute (RTI), and Stanford Research Institute (SRI).

A fourth Technology Application Team has been instituted at Abt Associates, Inc., an interdisciplinary research and consulting firm oriented toward urban problem solving activities.

The geographic distribution of the Application Teams and the special problem areas in which each team concentrates are shown in Figure 2 and Table 3.

The Applications Engineering Center (AEC) is part of the Division of Biomedical Engineering, Research Laboratories for the Engineering Sciences, of the University of Virginia School of Engineering and Applied Science. This group provides an adaptive engineering capability in addition to that of the Biomedical Application Teams and NASA field centers. Its basic function is to adapt NASA technology to the needs of a Problem Originator, where the Problem Originator is unable to adapt the technology through his available resources. This recent program innovation was established in response to a continuous need for reengineering or aerospace technology to meet nonaerospace requirements. Where appropriate, the Application Teams and NASA field centers have carried out a limited amount of adaptive engineering to facilitate and enhance the flow of technology to the public sector.

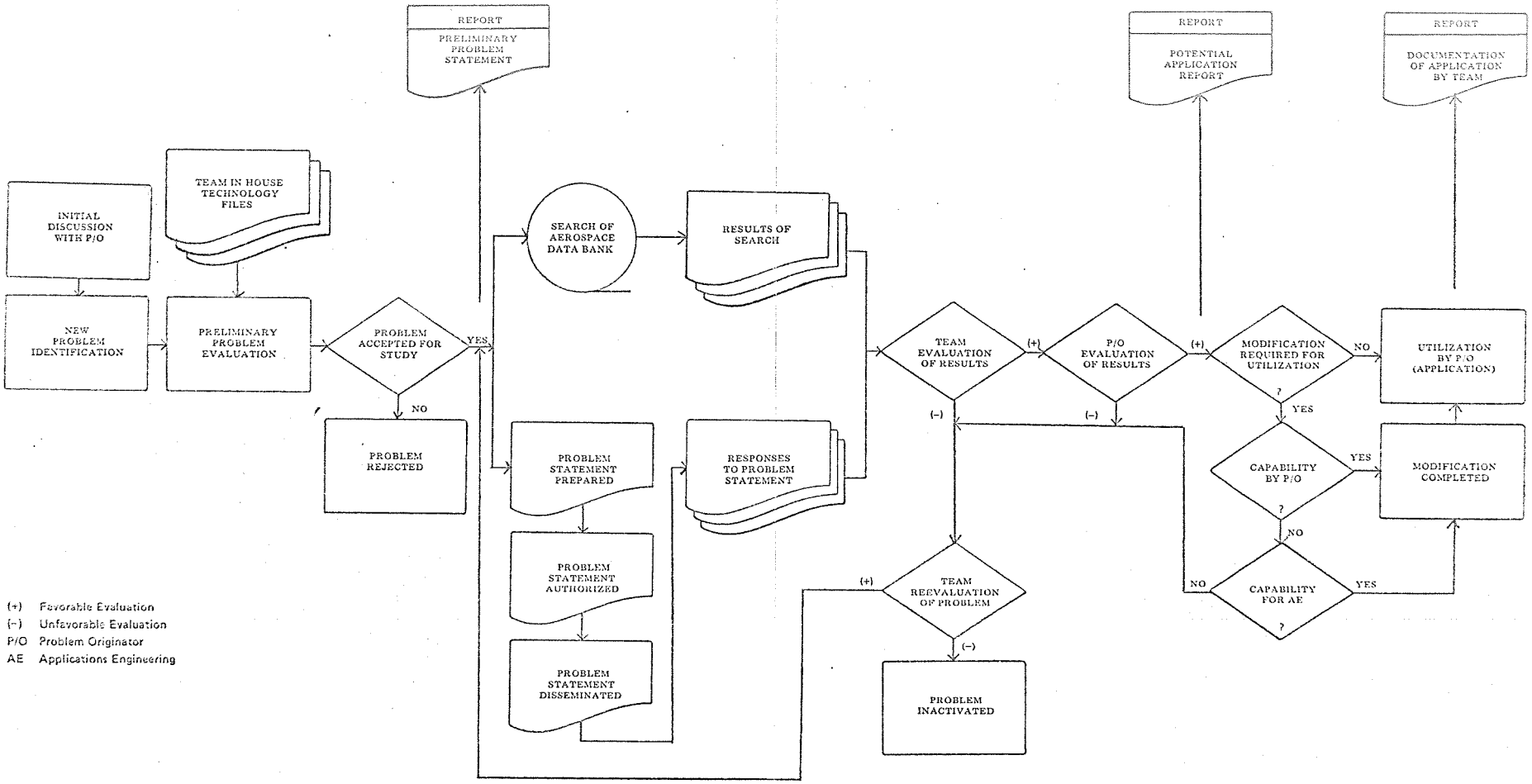
DEFINITION OF TERMS

In the Application Team Program, a number of terms have evolved which describe the elements and processes in this program. Because of their number and unfamiliarity to many readers, these terms are listed and defined here for easy and quick reference.

Fig. 1

Figure 1. Flow Chart of Basic Application Team Methodology

FIGURE 1: Flow Chart of Basic Application Team Methodology


REPORT
PRELIMINARY PROBLEM STATEMENT
REPORT
POTENTIAL APPLICATION REPORT
REPORT
DOCUMENTATION OF APPLICATION BY TEAM
INITIAL DISCUSSION WITH P/O
TEAM IN HOUSE TECHNOLOGY FILES
NEW PROBLEM IDENTIFICATION
PRELIMINARY PROBLEM EVALUATION
PROBLEM ACCEPTED FOR STUDY
YES
NO
PROBLEM REJECTED
SEARCH OF AEROSPACE DATA BANK
RESULTS OF SEARCH
PROBLEM STATEMENT PREPARED
RESPONSES TO PROBLEM STATEMENT
PROBLEM STATEMENT AUTHORIZED
PROBLEM STATEMENT DISSEMINATED
TEAM EVALUATION OF RESULTS
(+)
(−)
P/O EVALUATION OF RESULTS
(+)
(−)
MODIFICATION REQUIRED FOR UTILIZATION
NO
YES
UTILIZATION BY P/O (APPLICATION)
CAPABILITY BY P/O
YES
NO
MODIFICATION COMPLETED
CAPABILITY FOR AE
NO
YES
TEAM REEVALUATION OF PROBLEM
(+)
(−)
PROBLEM INACTIVATED
(+) Favorable Evaluation
(−) Unfavorable Evaluation
P/O Problem Originator
AE Applications Engineering

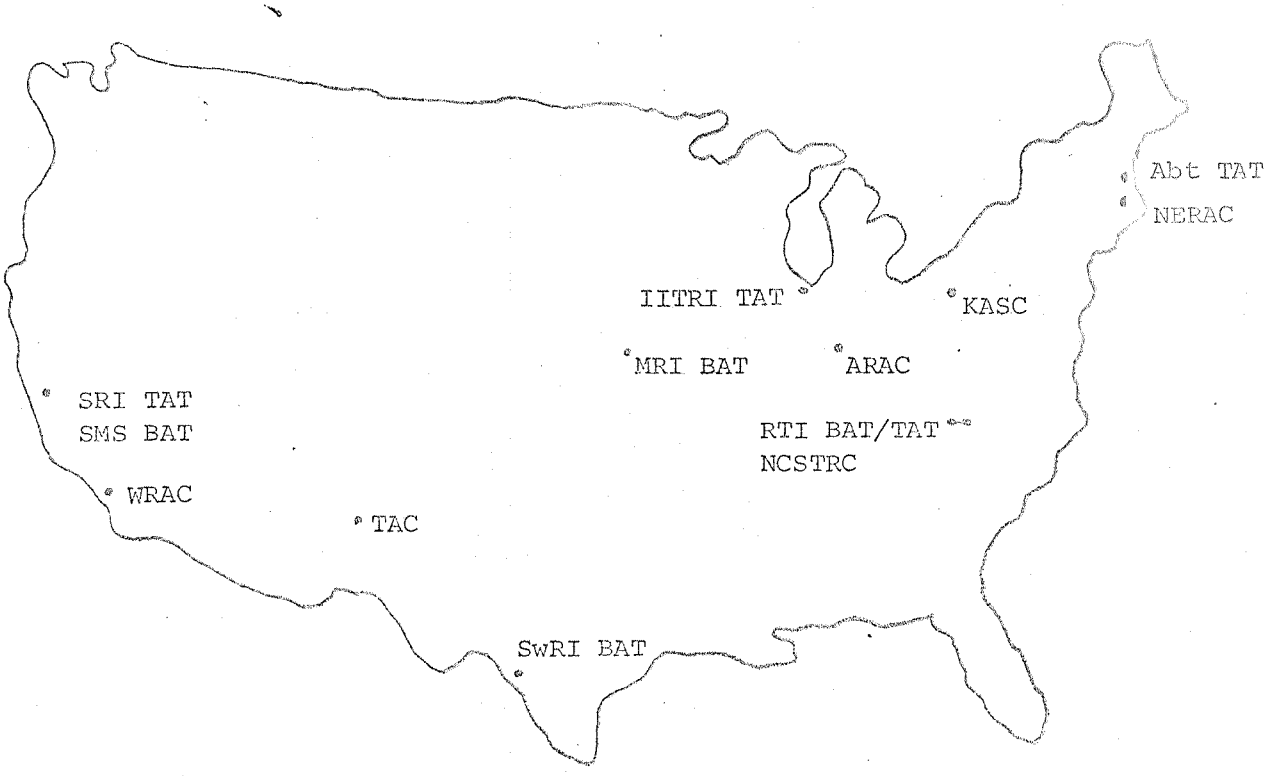


Figure 2. Geographic Distribution of NASA Application Teams and NASA Field Centers

Problem Originator or Researcher--An individual actively involved in an effort to reach a specific objective in biology or medicine and faced with a specific technological problem which is impeding progress toward that objective.

Participating Institution--A medically oriented educational institution, hospital, medical center, or government agency having as one of its organizational objectives the improvement of medical health care.

Consultant--A member of the professional staff at a participating user institution who has committed a portion of his time and effort to assist the Team in identifying and coordinating visits with appropriate problem originators at his institution, in understanding and specifying problems in biology, medicine, and the public sector, and in evaluating technological solutions to problems.

Application Team (Team)--A multidisciplinary group of engineers and scientists engaged in problem-solving activities in biology, medicine and the public sector with the specific objectives of effecting the application of aerospace technology to solve or aid in solving problems in medicine and the public sector and of understanding and optimizing the methodology for effecting such transfers of technology. The methodology used by the Team involves (1) problem identification, definition, and acceptance; (2) search for potential solutions to problems by manual and computer information searching, circulation of problem statements to NASA Field Centers, and contacts with NASA engineers and scientists; (3) evaluation of potential solutions; (4) implementation and adoption by problem originators of aerospace technology as

TABLE 3

PROBLEM AREAS STUDIED BY NASA APPLICATION TEAMS

TEAM LOCATION	PROBLEM AREAS
Abt Associates, Inc.	Urban Construction and Planning
IIT Research Institute Chicago, Illinois	Law Enforcement Mine Safety Water Pollution
Midwest Research Institute Kansas City, Missouri	Biomedicine
Research Triangle Institute Research Triangle Park, North Carolina	Air Pollution Biomedicine
Southwest Research Institute San Antonio, Texas	Biomedicine
Stanford University Medical School	Biomedicine (Cardiology)
Stanford Research Institute Palo Alto, California	Criminalistics Transportation

solutions or partial solutions to medical and public sector problems; and (5) documentation.

Problem--A specific and definable technological requirement that cannot be satisfied with commercially available equipment or through the application of information or knowledge available to the problem originator through routinely used information channels.

Technology Application--This is the implementation and adoption of an item problem in biology, medicine, or the public sector. The application involved is generally one which is different from that application for which the aerospace technology was originally developed.

Problem Statement--This is a concise, written statement of a problem which is used for communicating (1) sufficient details to allow a computer search to be performed by the information search specialists, and (2) sufficient information to enable NASA engineers and scientists to consider and suggest possible solutions to the problem.

Computer Information Search--This is a computerized information search of the aerospace data bank established by NASA and made available through six Regional Dissemination Centers in the United States. This data bank consists of the approximately 700,000 documents which have been indexed and abstracted in the Scientific and Technical Aerospace Reports (STAR) and International Aerospace Abstracts (IAA). The Computer Software Management Information Center, COSMIC, is essentially an RDC dealing with computer programs and documentation announced by NASA, AEC, or DOD. COSMIC may also do searches for the Application Teams.

Applications Engineering--This is the effort to redesign or reengineer aerospace technology for a specific, highly relevant biomedical or public sector application. The end product is usually a prototype which is to be carefully evaluated against performance criteria contained in a formalized evaluation protocol.

The two following chapters summarize recent achievements of the Biomedical and Technology Application Team Program. These summaries clearly indicate the significance of the specific problems, the relevance and application of NASA technology, and the complexities involved in achieving such Applications.

ACCOMPLISHMENTS OF THE BIOMEDICAL APPLICATION TEAMS

ACCOMPLISHMENTS OF THE BIOMEDICAL APPLICATION TEAMS

APPLICATION ACTIVITIES AND APPLICATIONS ENGINEERING EFFORTS

The Biomedical Application Teams have successfully completed several significant applications of aerospace technology during the period covered by this report. The applications were a result of continuous cooperation between the physician, the aerospace engineer and scientist, and the team member. These results demonstrate and affirm the active problem-solving technology applications methodology as a means of providing effective communication between the diverse fields of medicine and aerospace technology. Furthermore, this NASA Program illustrates that effective channels have been established for the transmission of information, ideas and technology between the physical and medical sciences.

Potential applications occur when the Biomedical Application Team has identified a solution that the medical researcher feels will solve his problem. There are many inherent barriers to biomedical technology application; the time required to achieve an actual application--a proven successful use of technology--may vary widely. The overall effects of the potential applications in the field of medicine will serve to add to the functional value of the Biomedical Application Team program in the future.

For problem-solution matches which have reached the status of potential application, NASA has undertaken applications engineering or equipment loan efforts, where appropriate, to assist the medical researcher in fabricating, obtaining, and evaluating the transferable aerospace technology. Detailed technical and biomedical criteria have been incorporated into the process of selecting projects to insure focus of this limited resource on significant problems which meet specific medical requirements. This section of the report is intended to provide a broad perspective of current Program activities. Application engineering projects that are nearing completion, but which became potential applications prior to the reporting period covered, are also included.

The following paragraphs describe a wide range of problem-solution matches to which aerospace technology is being applied.

Detection of Eye Tumors by Use of Radiation Probes. A valuable technique for the detection of eye tumors is based on the detection of beta radiation emitted by a radioisotope. The isotope, which is selectively absorbed by tumor cells, is first administered to the patient. It is then necessary to differentiate between different levels of radiated energy to detect tumors which are hidden from direct observations, or are in such an early stage of development that they cannot be detected by any other means. A measuring technique currently being used requires insertion of a dime-sized Geiger counter probe between the eyeball and the eye socket. The probe is both excessively large and insufficiently directional to be optimally sensitive, and cannot adequately determine the size of the tumor. Thus, there is some danger that the probe's inaccuracy will engender removal of an eye that could be saved.

A semiconductor radiation probe developed by NASA is sufficiently small to put in a slender probe; it can be inserted easily into the area behind the eye with minimum trauma. The probe, incorporating a thick film preamplifier

adjacent to the detector, has a signal-to-noise ratio that is amenable to recording equipment. It is highly sensitive, and provides a realistic measurement of the spatial and energy distributions of beta radiation. From the data gathered from many locations, the differences in isotope concentration can then be used to identify and outline the area of increased isotope uptake by suspected tumor cells, if they are present.

This information will be vital to diagnosis and therapy of the eye. More accurate determination of the distribution of the isotope by the clinician will make his diagnosis more accurate. This will reduce the present high percentage of false positive-tumor diagnosis, which results in erroneous removal of the eye. The Southwest Research Institute Biomedical Application Team is installing the radiation detector in a specially designed probe. It is also designing an instrumentation package to connect this device to various display and analysis systems.

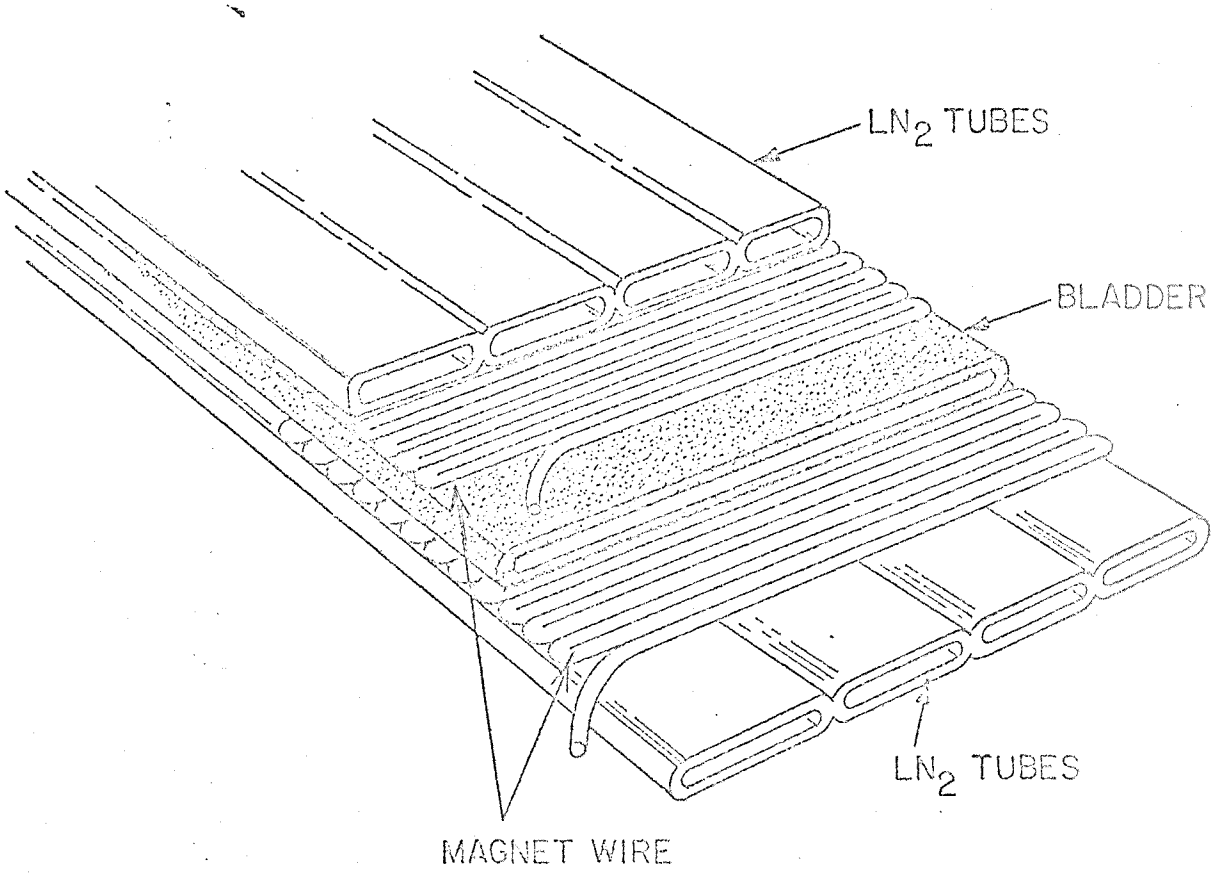
Method of Controlling Rate of Freezing of White Cells for Leukemia Research. A "cold sandwich," designed by NASA engineers at the Jet Propulsion Laboratory, may prove useful in freezing white blood cells in blood banks to be used for leukemia patients.

Leukemia is a form of cancer characterized by proliferation of white blood cells which are formed in bone marrow. It is treated by killing the cancerous white blood cells in the blood and bone marrow with the use of drugs or radiation. This process can cause loss of all bone marrow, inhibiting the production of normal white cells, so that a fresh supply of white cells is required for the patient. It would be desirable to have a white cell "bank" or frozen storage facility to provide sufficient white cells for leukemia patients. Currently, this is almost impossible due to destruction of white cells by existing freezing and thawing procedures, where the rate of temperature change is not constant. A method of freezing that provides for a constant rate of temperature change should solve the white cell destruction problem.

Researchers at the National Cancer Institute (NCI) described the problem to members of the Research Triangle Institute Biomedical Application Team. A detailed Problem Statement was then prepared by Team members and distributed to NASA scientists and engineers associated with this field for their suggestions. A group of engineers at NASA's Jet Propulsion Laboratory responded with a design of a heating and cooling "sandwich" which provides for controlled cooling (Figure 3). The NCI researchers reviewed this system and are investigating ways of having it fabricated.

The controlled freezing unit consists of a Teflon bladder containing the white blood cells, surrounded by heater grids, which are in turn surrounded by a cold tank through which liquid nitrogen flows. A temperature sensor in the bladder would continuously monitor temperature of the bladder contents and transmit this information to a modified Wheatstone Bridge circuit. This, in turn, would control the heater grids to provide a constant rate of cooling by the liquid nitrogen. If this design proves successful, it will remove a major obstacle to the availability of white cell blood banks and will lead to improved care and treatment of leukemia patients.

Scanning Tumors in Small Animals with Gallium-67. Gallium-67, a radioactive isotope, possesses the special property of concentrating in various types



White blood cells, unlike red blood cells, are destroyed by present freezing and thawing methods. Experiments indicate that the maintenance of a constant rate of cooling is essential to cell survival. By detecting the onset of freezing and then increasing the heat transfer rate during the release of latent heat at the freezing point, a nearly constant rate of cooling can be maintained. Cooling is supplied by the liquid nitrogen tubes and is controlled by heating the magnet wire. When the freezing point is reached, heating is discontinued so that a sharp increase in thermal flow occurs.

Figure 3. Controlled Freezing Unit

of tumors when administered orally or intravenously to a patient. The mechanism of gallium uptake is not well understood; it is not known whether there is a direct binding of gallium in the tumor tissue or binding to some other agent which in turn is concentrated by the tumor. Whichever is the case, Gallium-67 appears mainly in viable rather than necrotic tumors. In addition, studies indicate that Gallium-67 is superior to other commonly employed tumor-scanning agents in absolute tumor concentration and in ratio of tumor-to-normal tissue concentration. These observations are possibly the most significant recent developments in nuclear medicine.

By administering Gallium-67 to a patient and scanning the body with an instrument which can detect the presence of radioactive substances, the location as well as the size of a tumor can be determined. Radiologists currently employ a variety of camera and scanning systems which are useful in locating tumors in humans but are relatively ineffective in studying the

response of the tumor to therapy. In order to follow tumor growth on a day-to-day basis, a high resolution scanning system which is sensitive to Gallium-67 is needed. In particular, the scanning system has to be suitable for scanning the entire bodies of small experimental animals. Such a system would offer a unique opportunity to study methods of inhibiting or retarding tumor growth.

The National Cancer Institute posed this problem to the Research Triangle Institute Biomedical Application Team which, in turn, distributed a problem statement to the NASA field centers. A solution to this problem was proposed by the director of the Space Radiation Effects Laboratory (SREL) which is operated by a contractor under support from Langley Research Center. The suggestion involves the use of lithium-drifted germanium detectors to analyze the gamma radiation emitted during the decay of Gallium-67. The excellent resolution of these detectors should lead to easy identification of the primary radiation and will greatly simplify the collimation procedure since scattered radiation will normally be degraded in energy and therefore easily separated from the primary radiation of interest. Investigators at SREL are preparing a three-dimensional computer controlled scanning mechanism for use in radiobiological experiments. It was also suggested that this scanning mechanism might be used to control two lithium-drifted germanium detectors (operating at right angles to each other) to scan a tumorous source in three dimensions. A data acquisition system developed at SREL would move a small animal relative to the two radiation detectors and record the position of the animal at all times during the scanning procedure. The SREL system would then produce a map of the activity within the animal.

It appears that SREL is remarkably suited to solve the problem of scanning small animals, and they have agreed to demonstrate this system in the near future. Tumorous mice will be supplied to SREL by the National Cancer Institute.

X-Ray Microplanigraph. An aerospace method used for analysis of printed circuit boards is being applied to obtain improved X-ray techniques for cancer detection.

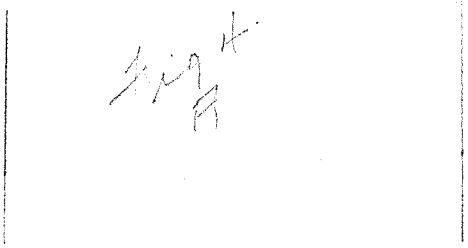
Cancer is the second largest cause of death in this country and, according to a recent survey, is the disease most feared by the American people. The state of cancer treatment today is such that generally those cancers which are found early can be successfully treated. The easiest cancers to detect are those that are on the surface of the body, and those most difficult to detect are those deep within the body. Thus, cancers arising deep within the body usually result in the death of the patient because detection of the cancer occurs too late.

It is desirable to develop an instrument capable of detecting tumors deep within the body. In addition, it is desirable to be able to determine if the tumor is malignant or benign and the extent to which it has spread. One common method of detecting tumors is by X-ray. Unfortunately, when the entire body is X-rayed, small tumors cannot be detected because the background level of the X-ray signal is vastly increased by the thickness of the body. It would be highly desirable to develop a technique whereby X-rays could be made of lamina regions only. Thus the X-rays could be made of thin laminae and smaller tumors could be detected. The basic problem then is to develop a

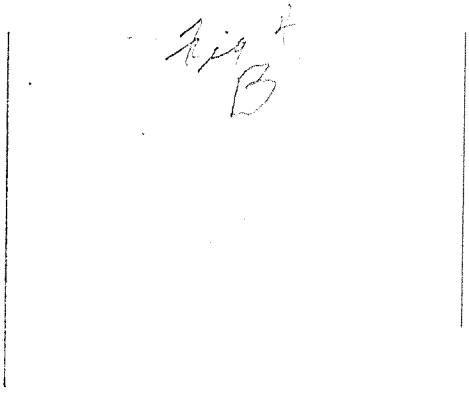
method whereby X-rays of thin laminae can be made of a patient instead of the conventional X-ray technique.

The technique of making X-rays of thin laminae with high resolution is called X-ray microplanigraphy. This technique has been theoretically possible for many years. Recently, a development in NASA has significantly increased the possibility of developing such a technique. NASA developed such a technique for inspecting multilayer printed circuit boards layer by layer with a resolution of 0.001 inch. This technique has been well developed by a NASA contractor at Illinois Institute of Technology (IIT). Basically, it involves moving the X-ray source and detector in a particular geometrical arrangement in such a manner that only thin laminae are measured. The work was funded by Marshall Space Flight Center (MSFC), and the Team learned of the work through a computer search. The Team then contacted MSFC for additional information and was referred to the IIT investigator. The Problem Originator has discussed this technique in detail with the NASA contractor and has decided that this work is highly relevant to his investigation. An example of the use of the technique is shown in Figure 4.

The Problem Originator has submitted a proposal to the National Institutes of Health for development of this device. It is highly significant that the entire proposal is based on NASA work. In addition to the NASA work at IIT, the Problem Originator has referenced a significant portion of the documents disclosed in the computer search. He has also acknowledged the assistance of the Team in the proposal. The Team feels that if this technique can be implemented, a major diagnostic tool for cancer will be developed.



A. Conventional X-ray Image of a Mouse



B. X-ray Planigraphic Image of a Mouse

Figure 4. Comparison of Conventional and Planigraphic X-ray Images

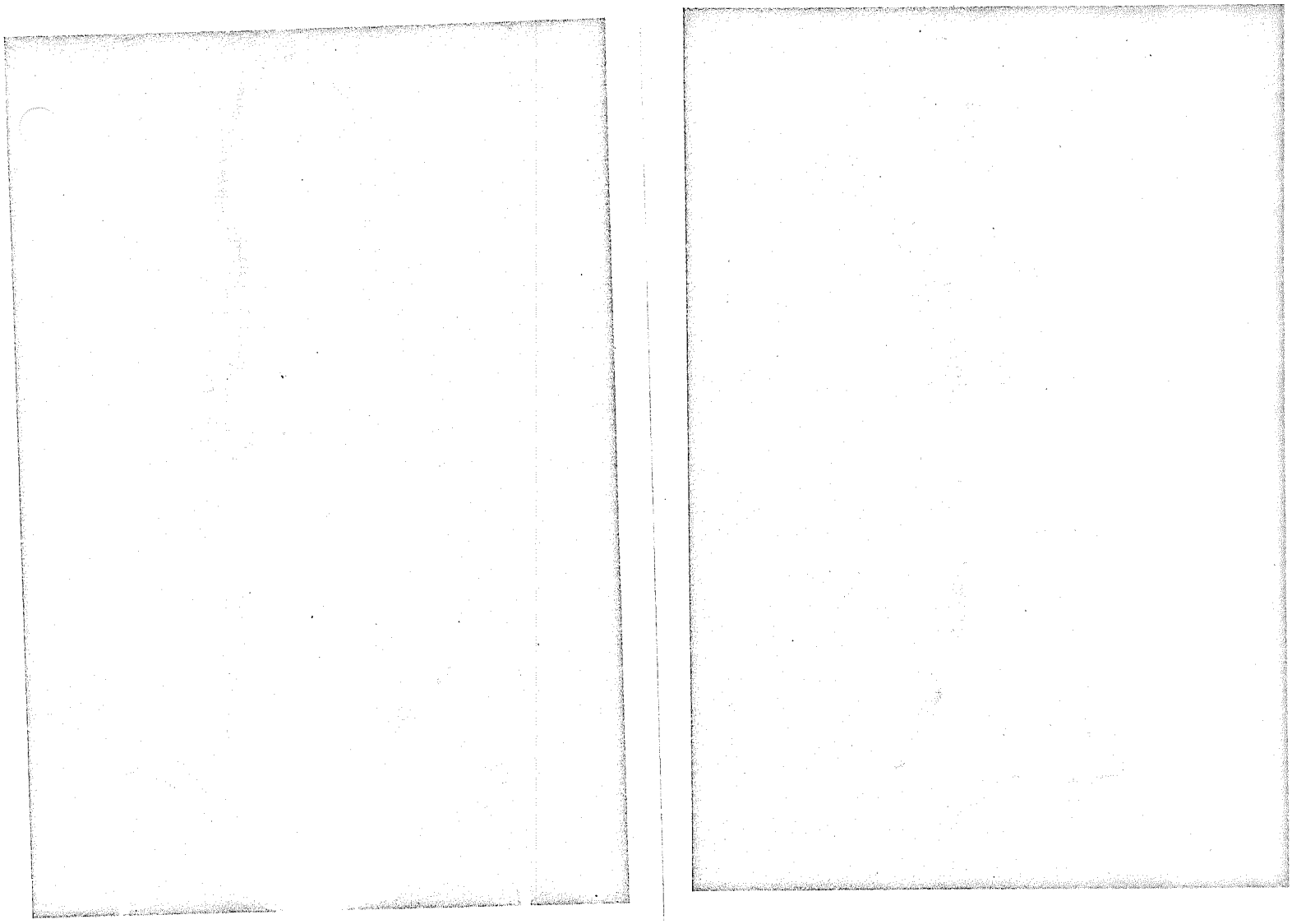


FIGURE 4: Comparison of Conventional and Planigraphic X-Ray Images

Noninvasive Continuous Monitor Detects Onset of Shock. Leukemia is a disease characterized by a self-perpetuating proliferation of white blood cell-forming tissue. An extensive National Cancer Institute program is directed toward finding the causes and cures of leukemia. The clinical phase of this program is concerned with early detection of shock. Shock, defined as the sudden reduction in the volume of circulating blood, frequently results from hemorrhage, infection, as well as other causes. If it is not recognized early, the damage is irreversible and rapidly becomes fatal. Thus a need exists for an accurate indicator of the onset of shock so that corrective measures can be taken in time.

An important measure of the onset of shock is reduction of blood pressure. The usual means of measuring blood pressure is by placing a cuff around the arm which is then inflated to higher than maximum blood pressure and slowly reduced. This method is quite inadequate for continuously measuring blood pressure if a patient is critically ill, since it disturbs him.

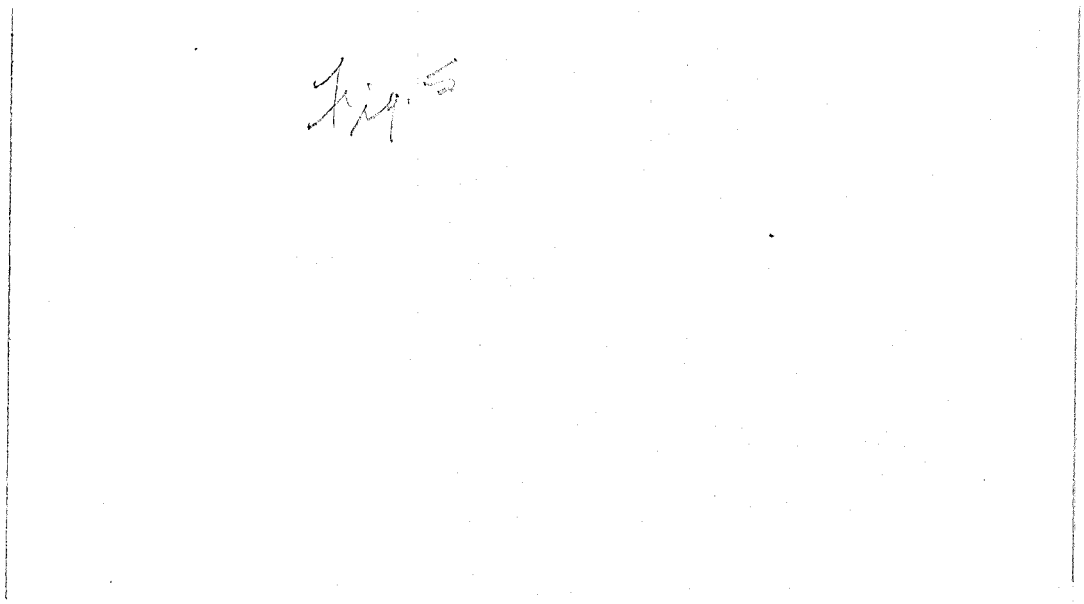
A device for measuring relative blood oxygen content has been identified: it is the ear oximeter (Figure 5), which permits detecting the onset of shock without disturbing the patient. The ear oximeter was adapted for use in the early astronaut program; it fits the ear similarly to a hearing aid.

The device is comprised of a small sensor mounted on the ear, and a small electronics package which can be placed at the patient's bedside. The absorption of infrared radiation by the blood is directly related to oxygen content of the blood. The onset of shock is accompanied by a reduction in the amount of blood and the oxygen content of the blood flowing through the earlobe. Change in the infrared absorption is detected and causes the device to set off an alarm that warns medical personnel to take corrective action.

The Ames Research Center has loaned the oximeter to the National Cancer Institute where clinical tests are underway to evaluate the unit. If the evaluation is successful, the unit will provide improved monitoring and care for leukemia patients.

Bone Density Measurement. Neoplasms such as tumors often secrete hormones which leach calcium from the bone. This can produce hypercalcemia (excessive calcium in the blood) and can produce a site in the leached bone that is vulnerable for cancerous cells. Hypercalcemia affects approximately 20 percent of lung cancer patients and 40 percent of breast cancer patients. Although hypercalcemia can be treated, its fundamental cause is not known. Present studies on experimental animals use X-ray absorption techniques to measure bone density as a means of following the progress of demineralization. This technique is not desirable for humans, since it requires the patient's exposure to numerous large doses of X-ray which must be continued for long periods of time.

A researcher at the Ochsner Foundation, studying the bone demineralization process, requested the Research Triangle Institute's Biomedical Application Team to determine if NASA had developed any techniques for determining the decalcification of bone. The Team found that the Marshall Space Flight Center had constructed a device (Figure 6) for just this purpose to be used in the NASA Skylab program. The propagation velocity of an ultrasonic pulse



The ear oximeter was developed to clip on to the ear and measure blood oxygen by absorption of infrared radiation. The output is related to both blood oxygen and pressure so that it may be used to provide for early detection of shock in hospital patients.

Figure 5. Ear Oximeter

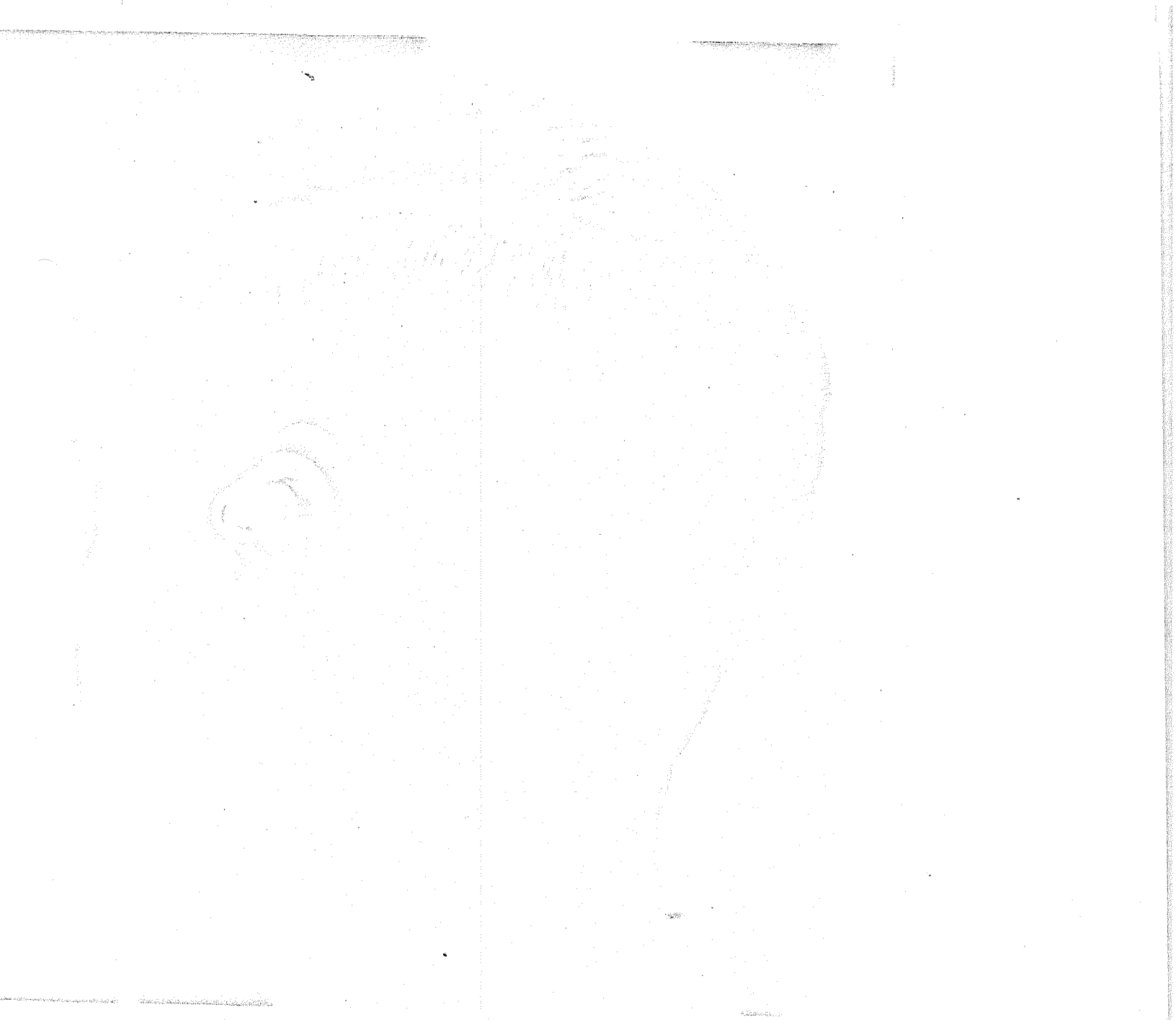


FIGURE 5: Ear Oximeter

Allows noninvasive determination of changes in the calcium content of bones. Previously developed techniques have been dependent on X-rays, making a long series of frequent studies impractical as they would have required subjecting a patient to an excessive amount of radiation.

Figure 6. Ultrasonic Bone Densitometer

FIGURE 6: Ultrasonic Bone Densitometer

along the length of a bone is measured by this device. Since conduction velocity is a function of material density, it should provide a good indication of any changes in the composition of the bone. This is a noninvasive test and merely requires accurate positioning of two transducers in good contact against the skin overlaying the bone being examined.

The researcher will perform these measurements on the rat tibia, with bone dimensions similar to the phalange bones of the human hand. It should therefore be possible to extrapolate his data and findings to measurements made on the phalange bones of humans in whom hypercalcemia is suspected. If the technique proves fruitful it will be important both as a diagnostic aid and to evaluate the efficacy and progress of therapy.

Improved Photographic Emulsion to be Used in Cancer Research. An improved photographic emulsion, being studied at NASA's Goddard Space Flight Center, is now being prepared for use in detection of radioactive cancer cells. The study of cancer in experimental animals can be facilitated by labeling the tumor cells with radioactive tritium. The tritium attaches itself to the DNA molecule and the division of the tumor cell produces new labeled cells. A process, called autoradiography is used to detect a radioactive cell; a film sheet of photographic emulsion is placed over the cell and exposed by the radioactivity. Existing film emulsions require an exposure of a month or more of exposure time. Investigators of the National Cancer Institute (NCI) needed a faster high resolution film so that the autoradiography technique could be used clinically to evaluate the progress of cancer in humans.

The Research Triangle Institute Biomedical Applications Team placed the NCI investigators in contact with a scientist at the Goddard Space Flight Center who had experimented with several types of specially prepared noncommercially available emulsions. His original interest in these emulsions had been to reduce the exposure time required to study the composition and energy spectra of low energy cosmic rays. Space and facilities have been made available for him at NCI, where he will prepare some improved emulsions for testing and evaluation.

Improved Lens for Cancer Research. In cancer research as in other advanced medical studies the basic unit of study is the human cell. Medical science demands fuller information on cellular action, and advancing technologies play a vital role in supplying information on intracellular components. A study being conducted at the National Cancer Institute uses an optical microscope controlled by a digital computer to obtain quantitative chemical data on cell mechanisms. It would scarcely be possible to pursue such a study otherwise, because of limitations of the human eye in the detection of minute changes. The same system can be used to delineate three-dimensional architecture of the human tissue.

This study has been underway for some time, but there has been difficulty in obtaining sufficient light intensity with the existing unit. This problem could be overcome by using a complex elliptical lens. The researchers have not been able to locate a commercial source for the needed lens. The National Bureau of Standards had offered to grind the lens if grinding specifications for the complex surface were made available.

The Jet Propulsion Laboratory has developed a computer program to design complex optical systems. This program had not previously designed elliptical lenses, but NASA personnel stated that the work can be done. The Fortran language computer program was shipped from the NASA-sponsored Computer Software Management Information Center (COSMIC) to the researcher, who is presently utilizing this program to design the improved lens.

The new elliptical lens will greatly clarify information derived from the human cell studies. The lens design is a critical element of advanced technology to further cancer research.

Automated Measurement from Coronary Angiograms. Technology developed at NASA's Jet Propulsion Laboratory (JPL) to enhance transmitted television images of Mars is being applied to techniques for measuring volume changes of the heart's pumping action. Under a current method for measuring heart volume, two X-ray images of the heart taken at right angles to each other are made after injecting a radiopaque dye into the arteries surrounding the heart. This technique allows measuring the changes in the volume of the heart by measuring the dimensional changes that take place outside of the heart, changes which can be measured by observing shifts in positions of the arteries surrounding the heart. The existing method for making these measurements is a laborious, manual process. Efforts are underway to automate this process. The Research Triangle Institute's Biomedical Application Team found information of the JPL image enhancement technique at the NASA Jet Propulsion Laboratory. This information was given to the investigator and through a NASA fellowship, he was able to spend a summer at JPL where he learned the image processing procedures which he applied to his problem. He has since purchased and installed the equipment necessary to more efficiently analyze the angiogram data.

The instrument is being used in conjunction with a Myocardial Infarct Research Unit funded by the National Institute of Health. Although, the system is presently functioning in a research capacity, the investigator intends to begin using it for routine diagnostic procedures in the fall of 1971. When this technique is fully implemented, it will be valuable in determining location and extent of loss of heart muscle function. It will also aid in determining effectiveness of surgical procedures designed to improve heart function by improving the blood supply to the heart.

Early Detection of Arteriosclerosis by Determination of Arterial Pressure Pulse Wave Shape and Transit Time. Arterial occlusive disease (arteriosclerosis) is a serious health problem in the United States; 38,102 deaths were attributed to arterial disease in 1965. It can be alleviated or corrected through various techniques. A major difficulty is that the disease is extremely difficult to detect in early stages before serious damage has been done. The disease often reaches crippling or catastrophic proportions before it is detected. The numerous and severe consequences of advanced arterial disease frequently lead to death without advanced warning. A researcher at Bowman-Gray School of Medicine expressed a need to the RTI BATeam for techniques to detect occlusive arterial diseases early enough to arrest their development.

The arterial pressure in the arterial system is a function of distance and time; hence it has wave properties. The wave speed of the pressure pulse

is related to the elastic modulus of the arterial wall. Also, wave reflections occurring in the arterial system perturb the pressure function. The elastic properties of the arterial wall change in humans with age and arterial disease. The biological problem is to detect, nondestructively, changes in the material properties of the arterial vessel early in the process of arterial disease. Change of arterial wall properties are thought to be related to wave speed or transit time of the arterial pulse. To validate the accuracy of this hypothesis, it is necessary to establish the relationship between the extent of arterial disease and the wave speed or transit time of the arterial pulse. An accurate means of determining wave speed or transit time will aid in the determination of this relationship. Consequently, it is essential to obtain reliable, accurate means of determining the wave speed and transit time of arterial pulses.

The Research Triangle Institute Biomedical Application Team suggested that an ultrasonic Doppler blood pressure measuring system developed by the Southwest Research institute's engineers for NASA would be capable of making the necessary measurements. Although some alterations must be made to the original system, they are not extensive and can be made easily. A two-channel unit will allow the Problem Originator to establish the relationship between arterial wall properties and transit time or propagation speed of the arterial pulse. This device should be able to determine the arterial pressure pulse wave shape at two points along an artery, and the transit time required for passage of the pulse from one point to another. If the pulse shape has changed downstream, a change in the dynamic elastic properties of the arterial wall can be suspected. By moving the measuring apparatus along the artery, local constrictions can be detected. If, during a series of such measurements along an artery, the wave shape broadened and the transit time increased as one progressed downstream on the artery, this might indicate the presence of diffuse arterial occlusive disease. Such an indication would be an invaluable diagnostic aid. If a physician can detect arteriosclerosis in its early stages, appropriate therapy can be initiated before damage develops.

Recording and Playback of EKG Signals via Home-Type Tape Recorders. Researchers at a major southwestern medical school, seeking an economical method for recording and playing back EKG (electrocardiographic) signals via low-cost home-type tape recorders, requested the assistance of the Southwest Research Institute Biomedical Application Team.

Many components of the EKG signal are considerably below the 60-Hz, lower pickup limit displayed by such recorders. Consequently, before such signals can be recorded on the low-cost recorders, they must be conditioned and modulated to higher ranges by means of a subcarrier oscillator having (1) a frequency response from dc to 100 Hz, (2) a low noise figure, and (3) feature battery operation to assure patient protection. While there are portable analog recorders on the commercial market which are suitable for the purpose, they are exceedingly expensive ($1625 for one available model). They also require a separate reproducer to play back recorded signals into a strip chart recorder or EKG apparatus, which costs as much as $3500. This is beyond the resources of many physicians. They clearly need a device within an approximate price range of $100 to $200 which has a built-in signal conditioner/modulator for EKG signal input to the recorder, and a signal conditioning demodulator for playback of the recorded signals directly into an EKG apparatus, oscilloscope, or strip chart recorder.

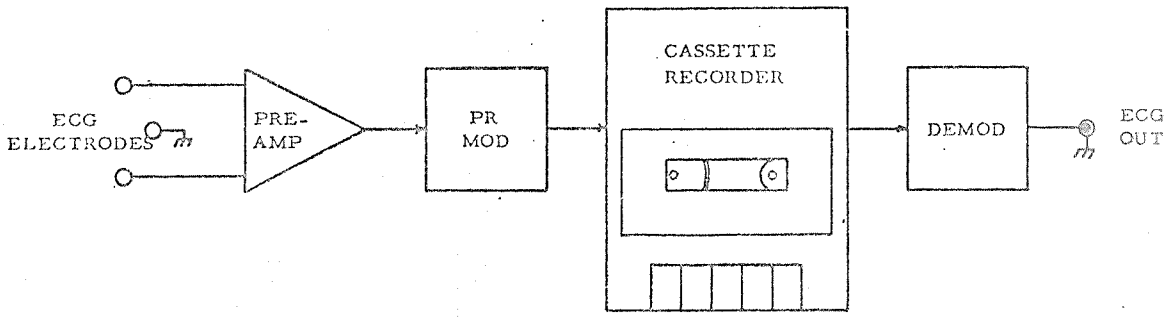
The advantages of having such a device readily available--as part of the physician's kit--are obvious. For example, by using the device, the physician could record the EKG of the cardiac patient within the privacy of his (the patient's) home--then replay the recorded signals into the EKG apparatus maintained in the physician's office, obtaining the readout for evaluation at his convenience. The approach also has great potential for medical research. For example, the physician could equip a cardiac patient with the recorder, and record the EKG as the patient went about his daily routine, exercised, or underwent stress. The patient would send the cassettes containing the recorded EKG signals to the physician at intervals, permitting him to evaluate the data at his convenience. Since variations from the normal EKG waveform patterns are considered to be good indicators of the severity of heart attack, reactions to various treatment programs, and likelihood of another heart attack, the availability of an economical means for monitoring the EKG, such as described, holds great potential for assisting in the battle to conquer heart disease through research.

Upon learning of the problem, the Biomedical Application Team initiated a search of the NASA Data Bank which resulted in retrieval of NASA Technical Brief of 64-10171 entitled Subminiature Biotelemetry Unit Permits Remote Physiological Investigations. The Tech Brief described a high performance, biopotential telemetry transmitter operating in the standard 88- to 108-MHz band, developed at NASA's Ames Research Center.

The Team found that the signal conditioning circuitry described was simple, relatively inexpensive to fabricate, and immediately applicable to the problem. They determined that the transmitter circuitry could be removed, and a hardware connection made to relay the EKG signal to the home tape recorder, after appropriate conditioning within the device. After recording the EKG signal on the magnetic tape cassette (wherever the patient may be), it is then played back through the signal conditioner built into the home-type recorder--with the output fed into an EKG apparatus, strip recorder, or oscilloscope for interpretation at the physician's or researcher's convenience. Figure 7 illustrates the EKG signal conditioner and its application.

Quantization of Heart Tissue Hardness. Post mortem examinations of various organs of the human body can reveal not only the cause of death, but often show other conditions that were affecting the person at the time of death. Research at Tulane's School of Medicine showed that in some cases, there was unusual softening of the heart tissue in patients who did not die of heart disease. The cause of this unusual softening was not known, but a number of factors were considered significant. For example, there was apparently a critical time period between the appearance of an infarction and a definite softness in the heart tissue. Reasons for this are being studied in experimental work, using rats whose blood is temporarily cut off from portions of the heart in order to determine changes in the heart tissue. Studies are also being conducted on human hearts in autopsy examinations, to determine whether this soft region can be attributed to any known condition of the human prior to death. In order to carefully characterize these soft regions, a means of measuring softness of the heart tissue is needed. The researcher's use of a conventional eye tonometer for this purpose had not been successful; the results had not been reproducible.

The Research Triangle Institute's Biomedical Application Team made a computer search of the NASA data bank for information on measuring hardness of



EKG Signal Conditioner

Fig 7a

With the modified low cost tape recorder, the physician can record EKG in the patient's home.

Fig 7b

A miniaturized version of the signal conditioner shown above is built into a low cost tape recorder.

Fig 7c

After returning to his office, the physician can reproduce the EKG signals on the same low cost tape recorder (which has a built-in demodulator), feeding the signals into either a strip chart recorder of EKG apparatus.

Fig 7d

The EKG recorder holds great promise for research applications such as monitoring changes in heart activity during exercise, stress, or other routine daily activity.

Figure 7. EKG Signal Conditioner

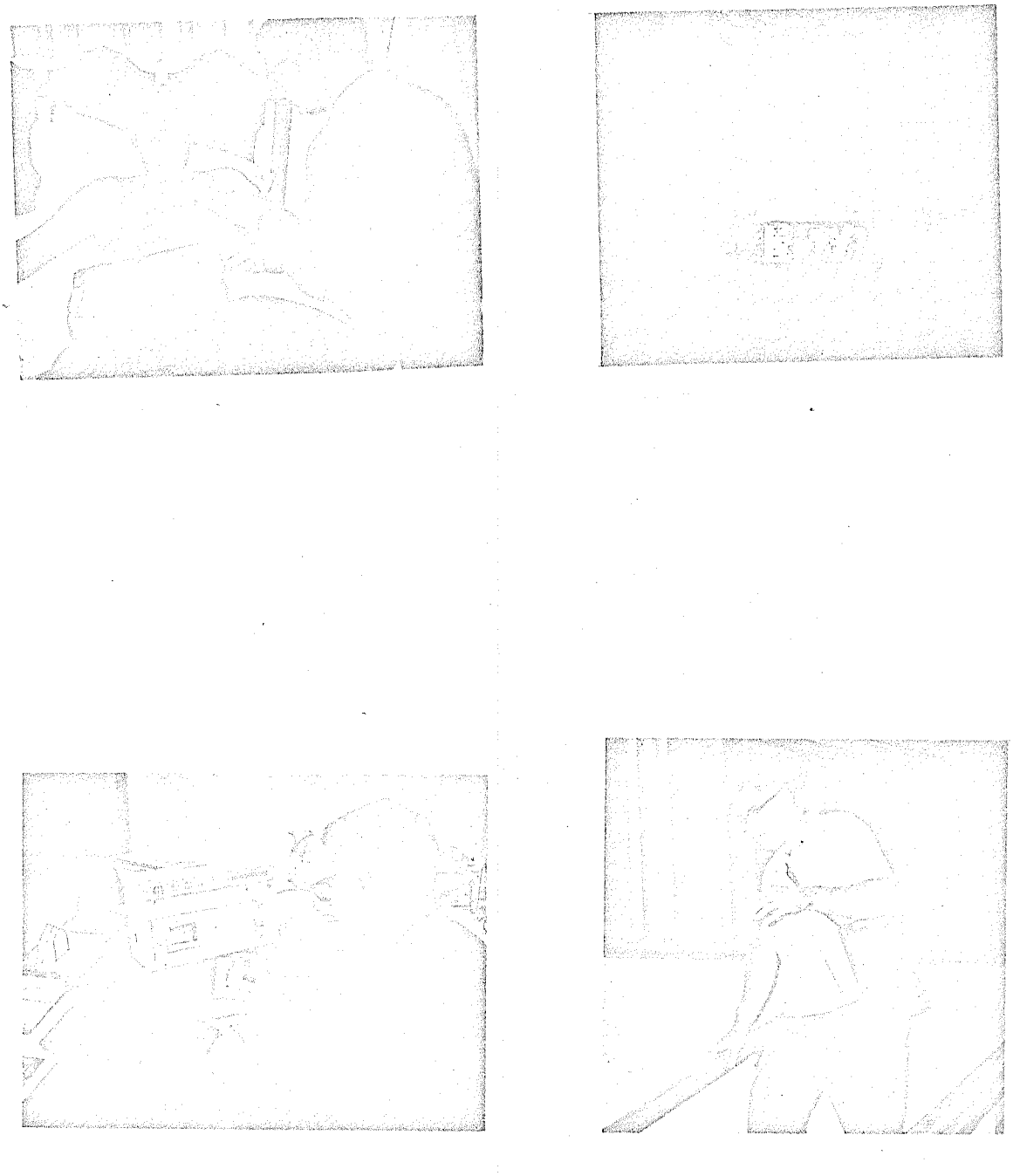


FIGURE 7: EKG Signal Conditioner

soft materials such as sponge rubbers and plastics. This search turned up experiments conducted at the Marshall Space Flight Center (MSFC) on a variety of hardness testing techniques. These appeared to be applicable to this problem. The Team visited MSFC for discussions with program personnel and discovered that a number of techniques in current use at MSFC were also applicable.

NASA personnel indicated the type of instrument that was required for this purpose. Of greater importance, they outlined the procedures necessary to obtain reproducible results. This information was then provided to the physician at Tulane's School of Medicine, who purchased the instrument recommended and incorporated the suggestions in his testing procedures. The experiments are currently underway, utilizing the NASA techniques, and the results to date have been successful. However, the researcher has determined the need for a tester for smaller areas, and the manufacturer has agreed to fabricate a special instrument according to his specifications which will allow testing of very soft, small regions. The results of this experiment are expected to add considerably to present medical knowledge.

Piezoresistive Semiconductor Functions as Heart Muscle Force Transducer for Heart Research. A physiologist at the Kansas University Medical Center, who has been studying the mechanical properties of the membrane surrounding the heart muscle, is using a miniature semiconductor strain gauge originally developed by a NASA contractor. The strain gauge enables him to make in vivo measurements of the tension in muscle fiber membranes, thus permitting him to acquire improved data on both the mechanical and electrical properties of the tissue. This data provides better knowledge of the basic physiological mechanisms of electrochemical stimulation and mechanical contraction within heart muscle tissue.

The piezoresistive semiconductor strain gauge now being used by the physiologist is identical to the strain gauges used by NASA. NASA incorporated these strain gauges into a miniature triaxial accelerometer used in studies of the effects of large accelerative forces on humans.

The appropriate transducer for this application was identified by the Midwest Research Institute Biomedical Application Team with the assistance of the Technology Utilization Officer at NASA's Ames Research Center. The physiologist was provided information which enabled him to purchase the transducer directly from the NASA contractor.

Instrumentation of Primates for Arteriosclerosis Research. Arteriosclerosis is one of the significant contributors to coronary disease. The buildup of extraneous material within the arterial system causes a reduction in the size (diameter) of the arteries which carry life-giving oxygenated blood to the body tissues. This narrowing of the arteries can occur systematically or locally. When the arteries are narrowed, the blood flow to the tissues is reduced. If the blood flow is reduced sufficiently the tissue being supplied by that artery dies. This is called an infarct.

Narrowing of the arteries also increases the impedance (resistance to blood flow) of the arterial system. In an attempt to maintain blood supply to the tissue, the heart must work harder, thus imposing an additional workload

on the heart. When constriction of the arteries occurs, there is an autoregulatory feedback mechanism which causes dilation of the arteries (vasodilation) in an attempt to compensate for reduction in blood supply to the tissue. In addition, this vasodilation can be accomplished by the administration of certain drugs (vasodilators). These drugs are frequently employed in treatment of arterial disease and associated problems where the objective is to improve the blood supply to the tissues. However, much is not understood about the mechanisms and effects of these drugs. This research program is designed to obtain this information on various vasodilators to permit their more effective use.

The investigator has accomplished extensive research to determine the effects of vasodilators on dogs using open chest methods. The next phase of the research program requires the use of rhesus monkeys using closed chest methods. The monkeys will be instrumented to measure blood flow, blood pressure, temperature, and ECG. The sensors will be implanted by open chest surgery. The monkeys will be monitored for three to six months during the course of the study. During this period, it is required that blood flow in the coronary artery, and pulsatile systemic arterial blood pressure in the aorta, be monitored for approximately one hour during each experimental session which might last up to four hours. The monkeys must also be restrained from activities which could impair or damage the instrumentation. Pressure and flow rate measurements must either be continuous or periodic at no less than one measurement per second. The pressure range to be measured was 50 to 250 mmHg with an accuracy of 1 percent, while flow rates to be measured range from 5 to 500 cc/min with an accuracy of ± 5 percent. As a result of the Biosatellite Program and NASA research involving monkeys, it was felt by the researcher that suitable physiological instrumentation restraint apparatus may have been built by NASA which would be potentially useful in this program.

Upon the request of the researcher, the Research Triangle Institute Biomedical Application Team ran computer and manual searches of the aerospace literature, and presented him with many documents of significant interest. In particular, information on the Electronic Research Center (ERC) tunnel diode pressure transducer was extremely useful. In addition to the NASA publications concerning the pressure transducer, information was obtained from Device Research Incorporated which is presently commercially marketing the ERC tunnel diode pressure transducer. The detailed information about pressure resolution, dynamic range, temperature compensation, and cost and delivery were of significant value. Additional information, considered to be very relevant to this problem, concerned the Mark IV ultrasonic Doppler instrument for indirect blood pressure measurement which was developed at the Southwest Research Institute. Detailed information including an instruction manual and a demonstration unit was borrowed from the Southwest Research Institute. Using the demonstration unit, the researcher was able to determine the applicability of this technique to the specific measurements required in his research program.

Additional useful information resulted from contact with the Biosatellite Project Office at the Ames Research Center. As a result of a telephone contact by the Biomedical Application Team, the office furnished complete information on the primate restraint system which had been developed at Ames for the Biosatellite Program. Specifically, complete engineering drawings of the primate restraint system were furnished to the researcher, and one of the animal restraint suits was mailed to the researcher by the Biosatellite Project Manager, for inspection.

This combined information has been used as background and supporting data in a grant request to the National Heart and Lung Institute for the establishment of an atherosclerosis research center at the Bowman Gray School of Medicine. This is a seven year program and would require the amount of $3.8 million in funding. In addition, the primate restraint system information has been used in the preparation of a three year grant request to the American Heart Association for the amount of $42,000. This program involves the study of atherosclerosis and coronary adrenergic response. The experimental animals to be used in this particular research program are similar in size and weight to the animals used on the Biosatellite Program so that the Biosatellite restraint units can be easily modified for this research program.

Means of Subjecting an Excised Heart to Physiological Pressure Pulses. The medical researcher is planning a research program in which methods for determining the infarcted area of human hearts will be evaluated. The overall objective of the program is to develop a means whereby the presence of infarcted areas on the heart can be detected and the location of the infarcted area delineated. During Phase I of this project, excised hearts having infarcted areas will be placed in a fluid-filled chamber simulating the chest cavity. Various techniques will then be evaluated for their effectiveness in detecting and locating the infarcted area. In order for this simulation to be realistic, it is necessary that the heart itself be subjected to pressure pulses of the magnitude and duration of the normal heart by means of an external pump. The researcher is seeking a pump which can simulate the volume and flow rates along with the pressure and waveshape characteristics of the normal human heart.

A manual search run by the Research Triangle Institute Biomedical Application Team revealed a NASA document, TND-6171, Pneumatic Artificial Heart Driving System Providing Quasi-Steady-State Regulation and Pressure Waveform Control, by scientists and engineers at the NASA Lewis Research Center. This document discusses the design of an artificial heart control system for reproducing the pumping and flow-regulating functions of the natural heart. The quasi-steady-state characteristics of the natural heart are reproduced in an artificial heart by means of feedback control. The system uses a specially designed servo-valve to provide adjustable pressure waveforms. This element of the artificial heart control system (the specially designed servo-valve) plus its control circuitry is directly applicable to this problem. The researcher has incorporated the unit into the planning for his research program as well as in a proposal to the National Heart and Lung Institute. Funds in the amount of $186,000 are being sought in support of this program. At the same time, the researcher has begun a research program to gather the preliminary data for Phase I. This work will no doubt be accomplished by the researcher even if funding cannot be obtained. The experimental apparatus necessary to perform Phase I are being gathered. In addition, information concerning the servo-valve and its control circuitry is being sought from the Lewis Research Center and the team is investigating the loan or fabrication of the servo-valve. The original valve is currently being used in an artificial heart program at the University of Utah.

Epicardial Electrodes. Early diagnosis of heart disease is an important factor in reducing the mortality from the major cause of death in this country. At the present time, the electrocardiograph is the principal tool for

diagnosing heart disease. The electrocardiogram is a measure of the electrical activity at the surface of the chest which is generated by heart action and is determined as a function of time. One of the most significant advances in electrocardiography is the recent development of body surface mapping or isopotential surface maps. This technique involves measuring the progress of isopotentials on the chest surface as a function of time. Rather than a time relation of a fixed point, the interrelation of a large number of points and, in particular, the phase relationships between these points is studied.

One of the basic difficulties in this type of study is determining how much information is actually required in order to map the potential distributions. This study attempts to determine whether or not the presently used 150 electrodes are actually required in order to determine the isopotential. Obviously, from a financial point of view, it is desirable to find the smallest possible number of electrodes which will provide a given amount of information. In order to obtain this information, the potentials generated at the surface of the heart and chest must be determined so that a correlation can be made between the two. This information is then fed into a PDP-12 computer for analysis on the amount of redundant information.

Although the major interest in the past has been in ventricular potentials, researchers have recently shown that the information at the atrial surface is of major importance--in particular, it is interesting that small transient relations on the atrial surface may be of major importance.

The Problem Originator's study involves attaching forty electrodes to the atrial surface. These forty electrodes provide detailed information concerning changes on the atrial surface. The electrodes will be attached during open chest surgery and must occupy an area not greater than 1 mm. The basic problem is to develop a method of quickly attaching these electrodes which will be implanted for a period of several weeks. The existing method of attaching the electrodes requires an inordinant amount of time; rapid attachment would not only save surgical time but would also reduce trauma.

NASA has developed a method for opening antennas in space by using a material with a mechanical memory. This material, called Nitinol, is annealed in a particular shape. When cooled to room temperature, the material can be deformed; then when it is reheated above the critical transition temperature, the material will return to its annealed form. This critical transition temperature can be adjusted to body temperature. Thus if electrodes made of Nitinol are annealed into a hooked configuration at body temperature and then lowered to room temperature, the hook shape can be straightened. Then when the straightened electrode is stuck into the atrial surface, the hook will immediately form and attach the electrode.

This method has been discussed with the researcher, and he is extremely interested in pursuing it. Samples of the material have been provided to the researcher and biocompatability studies are underway.

Surgical Suite Contamination Control. Although improved sterile surgical techniques, careful supervision, and other precautionary measures have done much to reduce infection to patients in hospital operating rooms, contamination by airborne bacteria could not be effectively controlled. It was not

until strict contaminant control requirements during the manufacture of aerospace components resulted in significant improvements in air handling technology, that a nearly particle free environment could be produced. As briefly discussed in a previous section, the division of cardiothoracic surgery of Washington University Medical School and Barnes Hospital in St. Louis, Missouri, were among the first to apply modern, aerospace developed cleanroom techniques to operating room use.

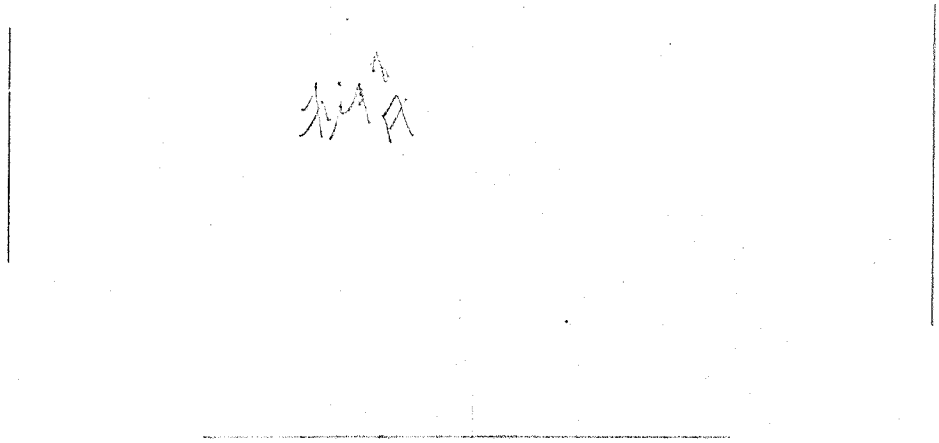
Through interaction between the Midwest Research Institute Biomedical Application Team and hospital administration personnel, NASA cleanroom data and commercially available ventilation components were utilized in the design to achieve a class 100 control of airborne particulate matter. The capacity of the system is 25 to 100 room changes per hour, a rate range achieved by use of a special fan blade configuration that permits a wide latitude over the pressure-volume efficiency curve. Maximal flow rate and linear velocity are 7,300 cubic feet per minute and 1.28 feet per second respectively. Net positive pressure relative to the adjacent induction, heart-lung, sterilizer, and monitor rooms is maintained by manually adjustable dampers and back pressure responsive valves in the volute chamber discharge plenum.

The system contains three graded disposable HEPA (high efficiency particulate air) filters with efficiencies of 40 percent, 94 percent, and 99.97 percent (Figure 8). The temperature and humidity are very closely controlled. The conditioned and filtered air is introduced into a false plenum above the ceiling and distributed through 96 square feet of perforated, epoxied aluminum panels.

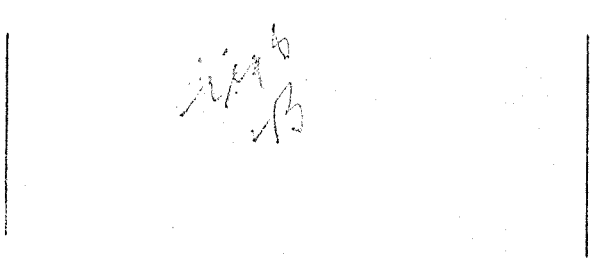
Prerenovation bacteriologic air sampling studies were performed for the 3 1/2 months prior to renovation. These studies are now being repeated at different airflow rates. Particle counting has been performed with a Coulter Model 550 monitor. Other special precautions in force in the room's operation are the extensive use of Barbac gowns and drapes to reduce lint; the absence of nonessential tables, hampers, stools, and personnel; and the stationing of the monitoring and blood gas analysis personnel in a separate room which communicates with the operating room by a sliding pass-through Lexan window. Audio communication is used for feedback of the test results. All supply cabinets are filled from behind to eliminate unnecessary traffic.

The cardiothoracic surgical suite is used for patients ranging from the newborn to the very elderly, with approximately 75 percent of all operations open-heart surgery, and the remainder of a "closed" palliative nature. During the six months that the operating room has now been in operation, no significant wound or prosthetic material infection occurred, and the system has yielded high flow ventilation with superior cleanliness and excellent thermal, humidity, and noise characteristics. The MRI BATeam planned a special conference on the use of cleanroom technology in surgical suites. The conference was held at Kennedy Space Center in May of 1971 and is discussed in a later section of this report.

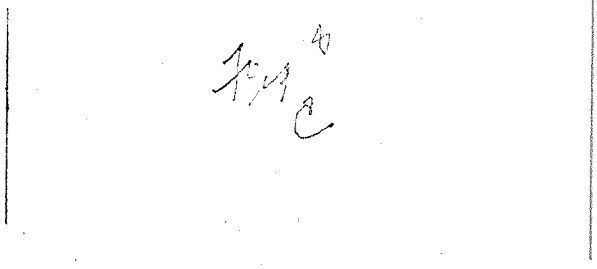
Economical Vital Signs Monitoring System Capable of Being Used with Conventional Nurse Call System. An economical vital sign monitoring system is not available presently for use within nursing homes and rehabilitation hospitals, where high risk patients are frequently found. A monitoring system which could be plugged into the existing conventional nurse (patient) call



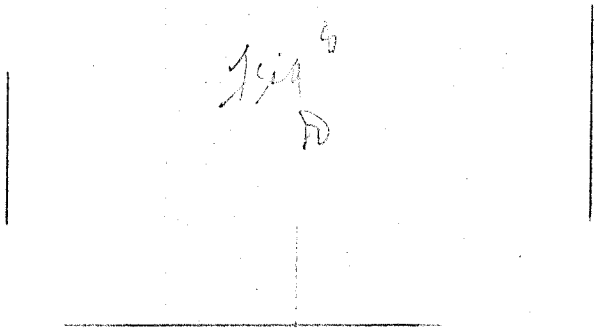
Schematic Side View of Ventilation System for the Operating Room. Capacity is 100 room changes per hour



Clean air distributes through perforated epoxy-coated panels with a maximum linear velocity of 1.27 ft/sec. A service column is in the upper left corner

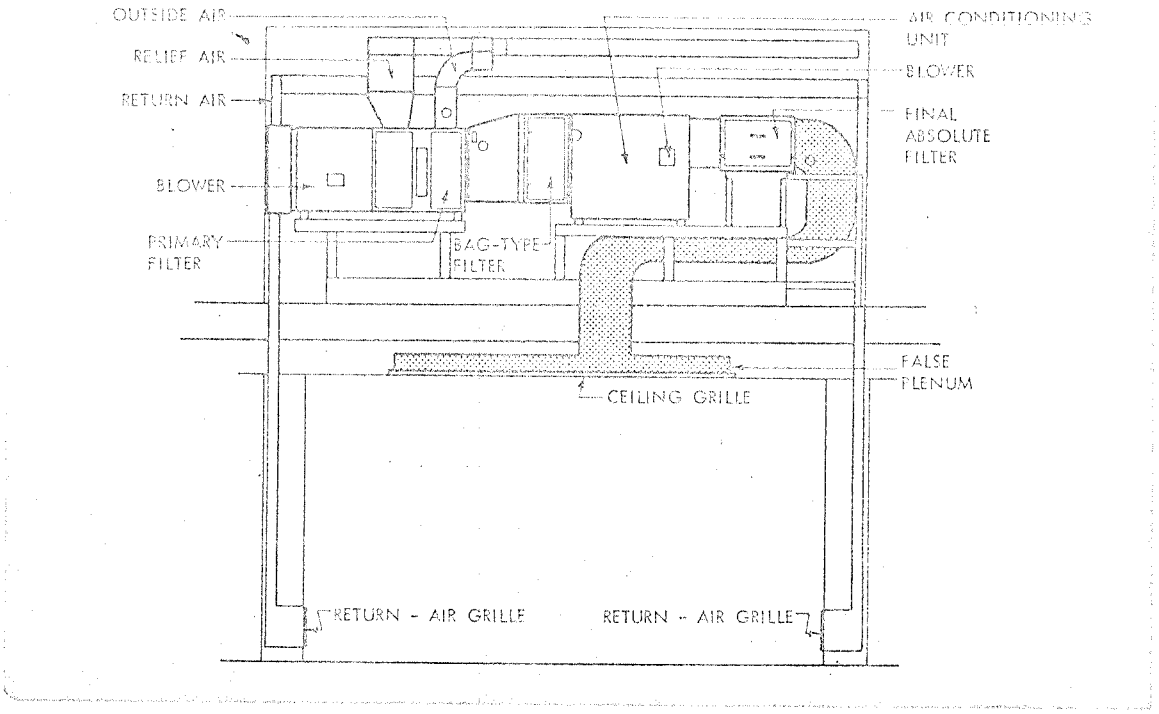


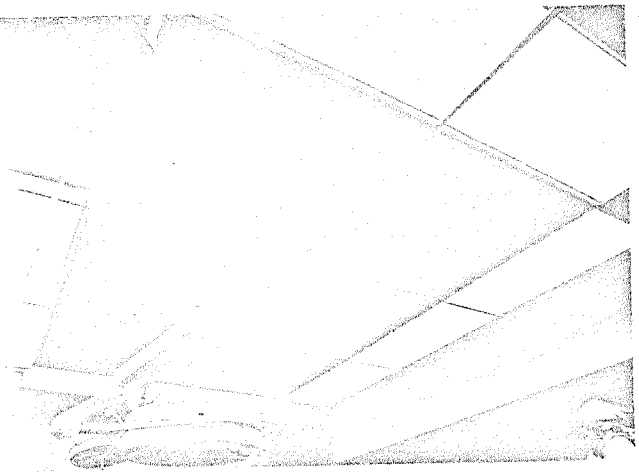
The ventilation system is located in a previous viewing gallery. The 99.97% efficient HEPA filter is on the right

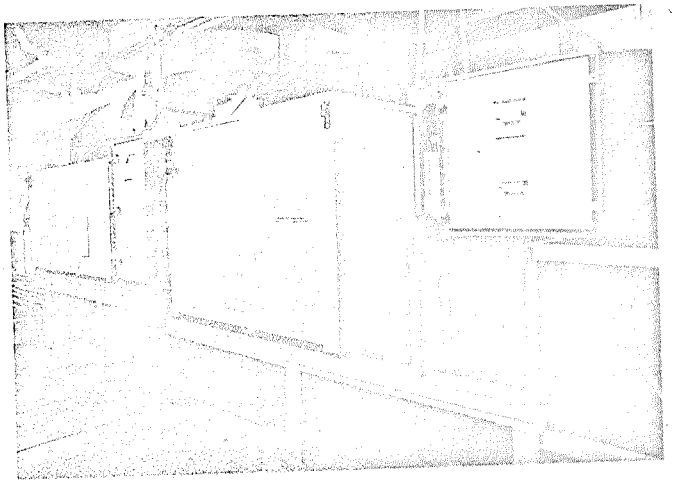


Ceiling grills cover patient and instrument areas. The monitor room window is on the left

Figure 8. Surgical Suite Contamination Control by Laminar Flow Techniques







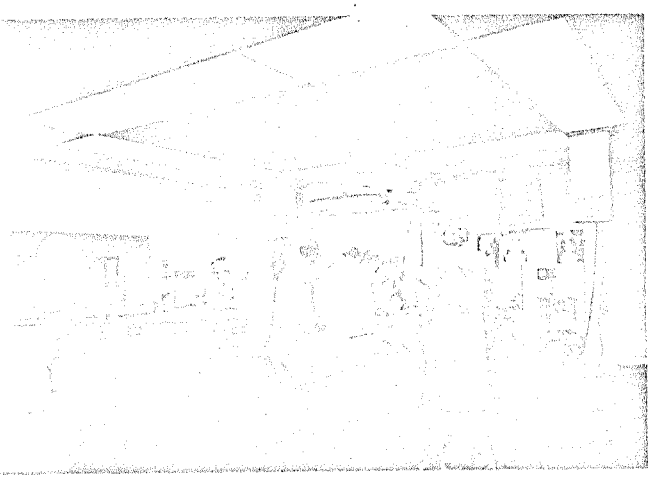


FIGURE 8: Surgical Suite Contamination Control by Laminar Flow Techniques

system could alert patient care personnel when a high risk patient's vital signs cease, so that immediate remedial action (e.g., external cardiac massage) could be taken to resuscitate the patient. Nursing homes and rehabilitation centers generally are not financially able to afford intensive care units featuring such alarms, due to high cost. Availability of an economical, reliable, and easy to operate alarm system which can be plugged into the existing outlet for the nurse (patient) call system would be a valuable alternative to the more sophisticated intensive care alarm system. The alarm envisioned could be moved from location to location as needed, since it would merely plug into the conveniently placed nurse (patient) call system outlet.

Such a monitoring system was developed by members of the Biomedical Application Team at the Southwest Research Institute at the request of one of the large rehabilitation centers with which they are involved. Physicians at the rehabilitation center thought that the availability of an inexpensive vital signs alarm which could be used readily outside of the conventional intensive care setup would hold great potential for saving lives of high risk patients in large medical care institutions where intensive bedside nursing care is not readily available. The BATeam located a number of aerospace related electronic physiological monitoring circuits which were applicable to this problem. Funds were provided by the Technology Utilization Program to fabricate a prototype of the cardiac/respiratory monitor for evaluation in the rehabilitation center.

This device has the ability to monitor the ECG signal; and by proper placing of the electrodes, respiratory information can also be monitored. When either component is missing, this unit will give an alarm via the local Nurse Call System installed in an institution.

The Monitor consists of three sections: an ECG Signal Conditioner, an ECG/Respiration Signal Processor, and an Alarm Unit. The ECG Signal Conditioner receives the ECG signal via either leads placed on a subject or through the ECG Isolator, which is a device that provides electrical isolation of the subject from the Monitor and other equipment. The level of the ECG signal is adjusted to permit proper operation of the Processor circuitry. An output is provided for monitoring and recording of the ECG signal. The ECG/Respiration Signal Processor receives the ECG signal and continually adjusts itself to the amplitude of the R-wave of each cardiac cycle. With proper placement of the ECG electrodes, the R-wave amplitude will vary directly with respiration and the processor will provide a signal dependent on the respiration of the subject. A change in the normal respiratory cycle of the subject or a loss or severe change in the ECG signal will be reflected in the output signal of the processor. The Alarm Unit will actuate a relay, closing the switch of an existing Nurse Call System, giving notice that some disturbance has taken place either with the equipment or the monitored functions of the subject. The unit will now actuate the alarm relay as long as the signal from the Signal Processor is within certain predetermined limits. The Cardiac/Respiratory Monitor is portable and powered by 115 volts a.c. (available in all rooms of most hospitals or rehabilitation centers). An adapter can be easily provided to go from the output of the Monitor to the input of the existing Nurse Call panel.

Beta Radiation Catheter Probe to Monitor Cerebral Blood Flow. There is a need for an improved technique to continuously monitor the cerebral blood flow

of head injury patients over an extended period of time. Present techniques require inhalation of a radioisotope and the frequent withdrawal of many blood samples for analysis to determine arteriovenous concentrations of the isotope. Monitoring of cerebral blood flow is necessary to determine therapy effectiveness. This technique produces patient discomfort and requires cumbersome equipment which must be maintained in a sterile condition. It provides few data points for assessing the blood flow, yet continuous determinations over extended time periods are needed to provide optimum analytic effectiveness.

A semiconductor radiation probe capable of continuously monitoring blood flow by detection of weak beta radiation from the isotope was developed by NASA. It can be mounted in a small double lumen catheter, making it easy to insert at the proper point in the blood stream. The probe has a low signal-to-noise ratio and provides good measurement of the spatial and energy distributions of radiated electrons and protons. The use of this probe will enable the physician to continuously obtain data. One catheter-mounted probe would be placed in the carotid artery to monitor the isotope concentration in the blood being supplied to the cerebral area. (A lumen located near the tip of the radiation probe would allow one blood sample to be taken for blood gas analysis.) A second catheter-mounted probe with appropriate lumen would be placed in the jugular vein to get a similar measurement on blood flowing from the cerebral area. From the data collected at these two points the cerebral blood flow is easily determined; the blood flow data are indications of the extent of head injuries, progress towards recovery and the effectiveness of therapy.

The radiation probes are being mounted in suitable catheters by the Southwest Research Institute BATeam who will also provide the investigator with the necessary electronic devices. The system will then be tested in several animals before being given to the physician for clinical trial and evaluation.

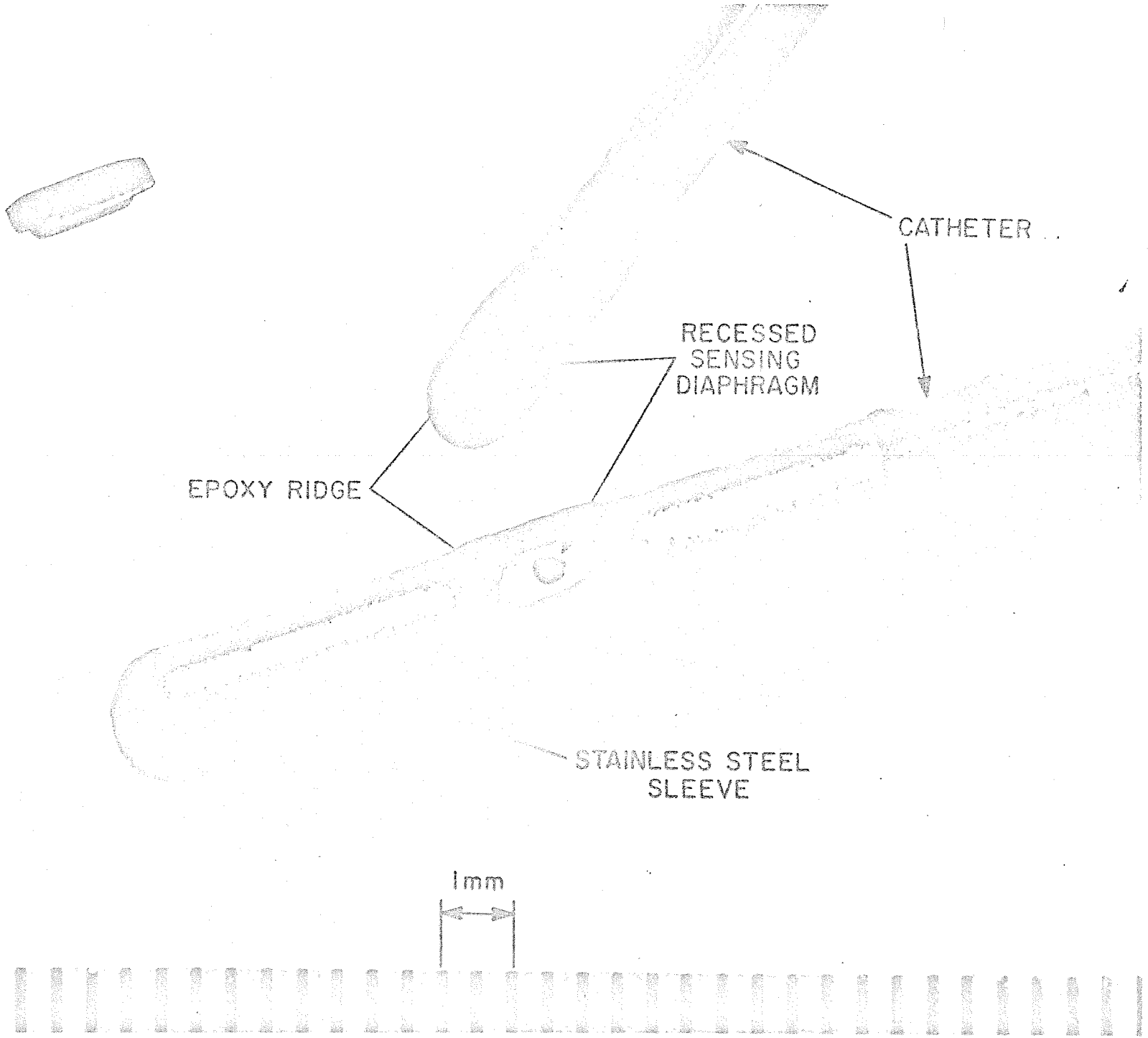
Tunnel Diode Transducer Used as a Biomedical Sensor. The human body is dependent on several fluid transport systems for moving nutrients, gas, enzymes, hormones, and wastes from one part of the body to another. Blockage or excessive pressure within one of the fluid transport systems can result in various pathological conditions. Diagnosis and determination of proper therapy could be improved by a small pressure transducer (diameter less than 1 mm) with the proper sensitivity and range. Inserted into a vein or artery, or any of the other fluid transport systems it would be valuable in assessing the condition of the circulatory, cerebrospinal, lymphatic, and urinary systems.

Research and development at NASA's Electronics Research Center developed a suitable pressure sensor (Figure 9). New semiconductor fabrication techniques were utilized for a transducer with resolution of greater than 0.1 mm Hg with an overall diameter of less than 1 mm and low power requirements, which has been designed, fabricated and tested. Since the NASA Electronics Research Center was closed last June, the researcher has formed his own company, Device Research, Inc., which has made this device commercially available. This device will greatly aid many investigators concerned with measurement requirements. The frequency response of this device is flat to greater than 4,000 Hz.

Fig 9

Originally developed by NASA/Electronic Research Center and now commercially available, represents a significant advance in the state-of-the-art.

Figure 9. Tunnel Diode Pressure Transducer


CATHETER
RECESSED
SENSING
DIAPHRAGM
EPOXY RIDGE
STAINLESS STEEL
SLEEVE
1mm

The high frequency response allows the detection of high frequency heart and valve sounds and permits more accurate measurement of intravascular and intracardiac blood pressure waveforms. Mounted on the tip of 100 cm catheters, the pressure transducer may be introduced into an artery or vein through a standard 17-gauge thin-wall needle (ID=1.1mm), a size routinely used for humans. It will probably replace techniques which use fluid filled catheters for measuring ventricular heart pressures and those procedures which require cutdowns on arteries for the insertion of the catheter. Measurement techniques currently in wide use employ a fluid-filled catheter to transmit internal pressures to external transducers. These are subject to distortion and error introduced by the long fluid column through which the pressure pulse must propagate before being measured. The improved device will allow physicians to obtain a more accurate indication of the intracardiac pressure while reducing risk to the patient. Figure 10 illustrates comparative characteristics of the tunnel diode transducer and other commercially available transducers.

Each of the three NASA Biomedical Application Teams has purchased one of the pressure transducer systems and has made it available to a number of medical researchers who had expressed interest in such a device. It is currently being used in studies on an artificial heart, pediatric cardiology and urethral pressure/flow studies.

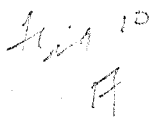
The National Heart and Lung Institute has used the tunnel diode transducer to measure directional stresses within the myocardium (heart muscle) of a calf. The researchers have been able to record data which were never before measurable by recording hydrostatic pressure. The measured myocardial stresses are found to vary under conditions such as a local infarction and various drugs. Although these studies have begun only recently, the early results are quite promising and considerable effort will be directed towards further investigations.

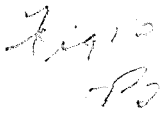
Wright Spirometer to Aid Surgical Anesthesia Monitoring. The Wright Spirometer, modified by NASA to measure the respiration rate and volume in test pilots, shows potential application to monitoring respiration of surgical patients under anesthesia.

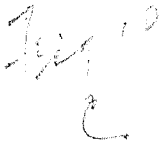
An anesthesiologist at the Kansas University Medical Center noted the problem of continuously observing the respiration state of an anesthetized patient. The anesthesiologist saw a need to accurately monitor the breath-by-breath respiration volume and flow rate of patients undergoing surgery, for an instant indication of their well-being and for a permanent record on the patient. The modified Wright Spirometer, developed by a contractor to NASA's Flight Research Center, was identified and suggested to the investigator by the Midwest Research Institute Biomedical Application Team.

Preliminary tests of a prototype spirometer in the intensive respiratory care unit at the Massachusetts General Hospital are favorable. They indicate that while this prototype is in need of modification, it would provide valuable information, heretofore unobtainable, on patients' respiratory functions.

A suitably modified spirometer (Figure 11) is being fabricated at the University of Virginia's Division of Biomedical Engineering as part of their NASA-funded Applications Engineering project. It provides a digital readout of up to 20 liters per minute, with this data being updated every 30 seconds.



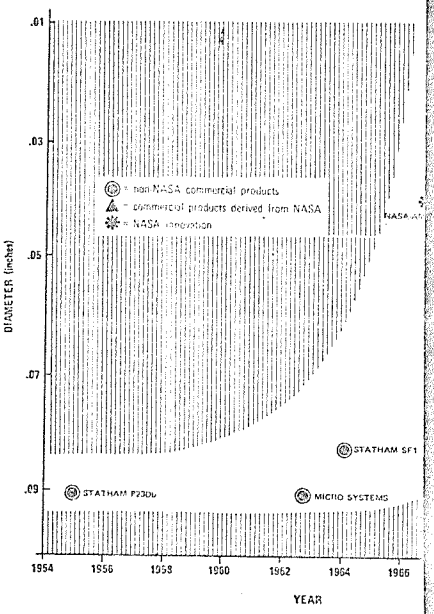




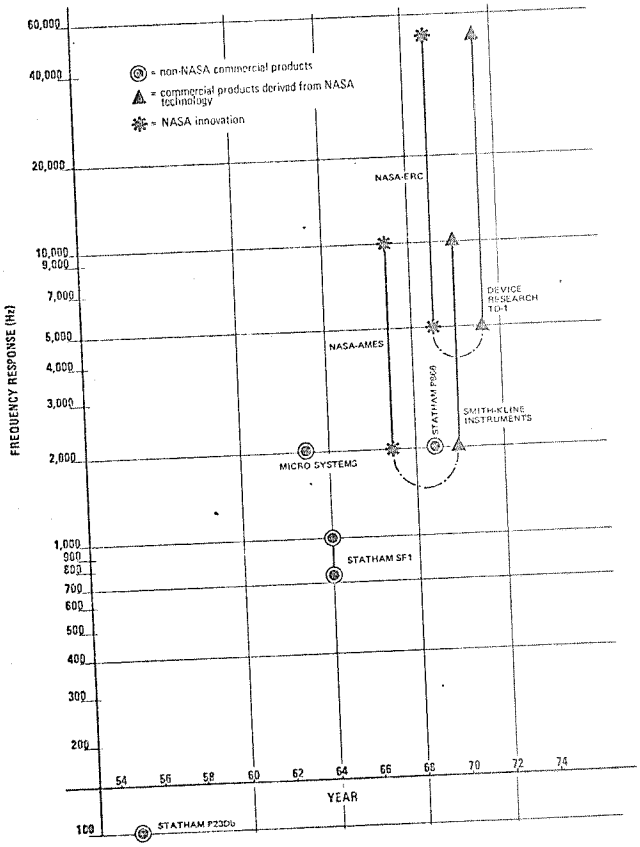
Tunnel diode pressure transducer developed by NASA Electronic Research Center represents a significant advance in the state-of-the-art. Its small diameter, high resolution (0.5 mm Hg), broad frequency response, low excitation voltage, and controlled thermal zero shift should improve the quality of data available to physicians and researchers in studies of the cardiovascular, cerebrospinal fluid, and urinary systems.

Figure 10. Characteristics of Miniature Pressure Transducers

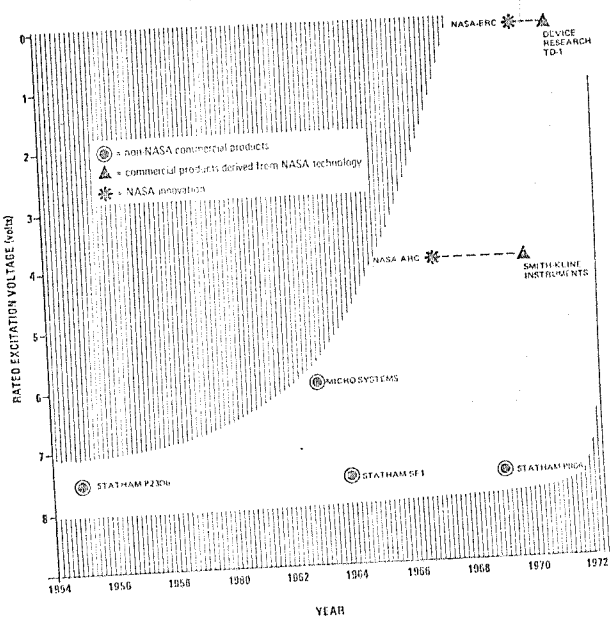
DIAMETER OF CATHETER TIPS



FREQUENCY RESPONSE OF TRANSDUCERS



RATED EXCITATION VOLTAGE

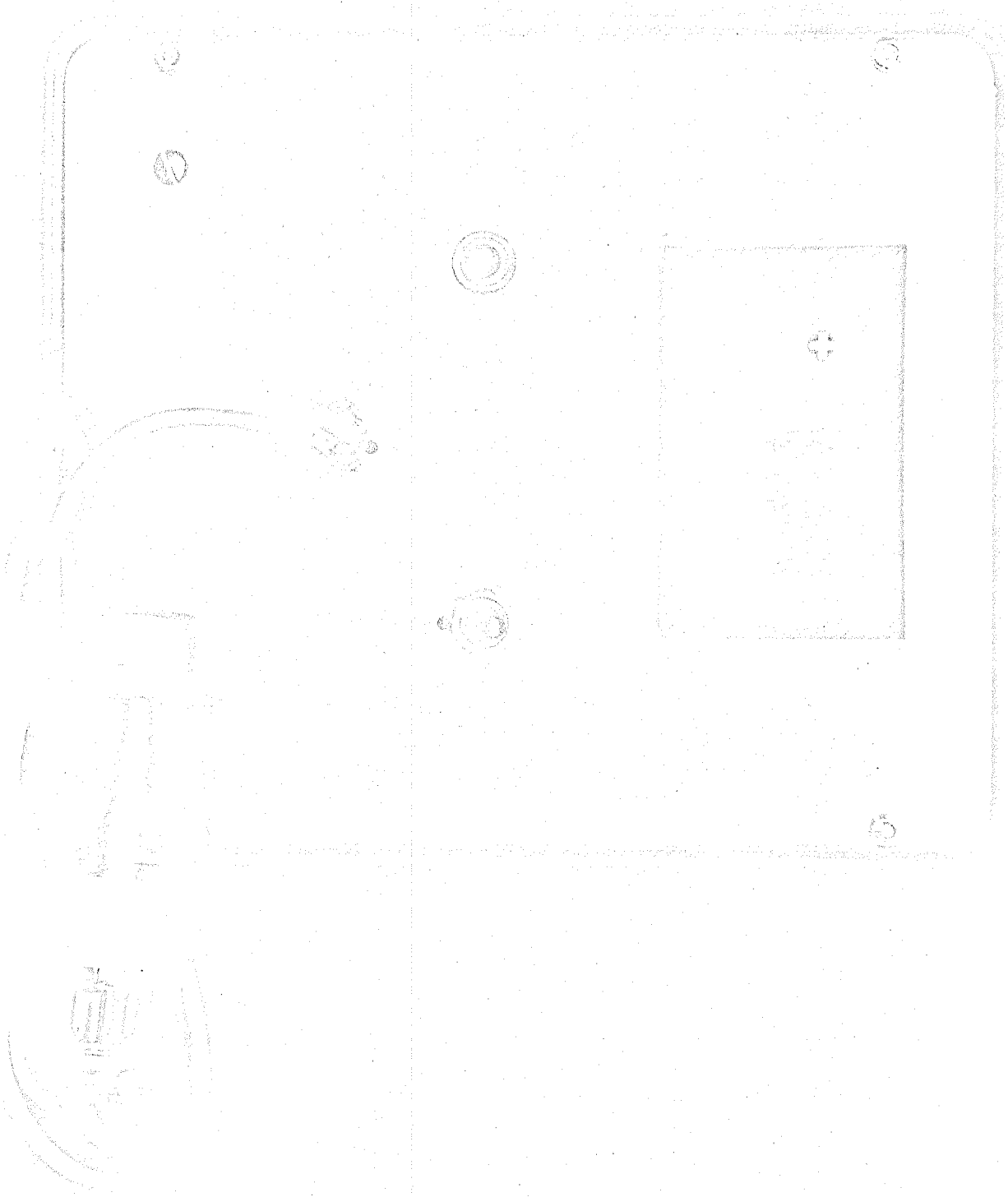


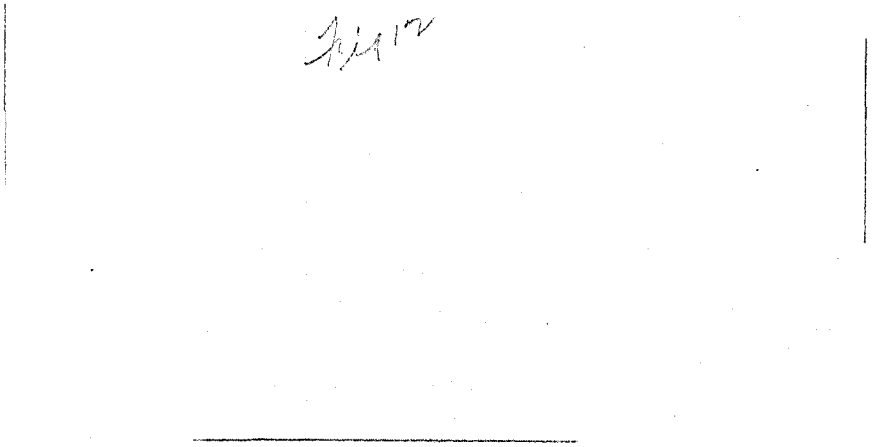
ire Pressure Transducers

Fig 11

Constructed by the University of Virginia Department of Biomedical Engineering Applications Engineering Project. Provides a digital display of a patient's minute respiratory volume. Used by an anesthesiologist, it will permit more precise monitoring of a surgical patient's respiration.

Figure 11. Modified Wright Spirometer





The Respiration Alarm detects the thermal fluctuation of the air as a patient is respired. When a failure is detected, an audible alarm is actuated. This will eliminate much of the monitoring which is presently done by a nurse and will free her for other duties.

Figure 12. Newborn Infant Respiration Monitor

Newborn Infant Respiration Monitor. Researchers at a West Coast children's hospital solicited assistance from NASA's Biomedical Application Program in the development of economical, reliable means for indicating the occurrence of apnea (respiratory arrest) in infants. During respiratory arrest, the infant simply ceases to breathe, with death rapidly ensuing unless remedial measures are undertaken to restore breathing.

After birth, a number of infants are subject to respiratory distress due to various reasons. A means of monitoring the respiratory function of newborn infants (particularly those who are believed to have physiological impairment of the pulmonary system) was urgently needed, since it was impractical to provide continuous monitoring by stationing nursing personnel at the infant's cribside.

A search of the NASA Data Bank produced several documents describing techniques for automatic monitoring (NASA Tech Briefs 64-10365 and 64-10170) which, by modifications, could solve the problem described above. The Biomedical Application Team replaced the EKG preamplifier described in the latter reference with a thermistor bridge network, resulting in a very economical, reliable means for monitoring respiration.

Input to the system is provided from a sensor attached with a microminiature connector to the infant's airway. This permits competent operation of the monitor and allows for autoclave sterilization of the airway as needed. The redesigned transmitter (Figure 12) hangs on the isolette and transmits a

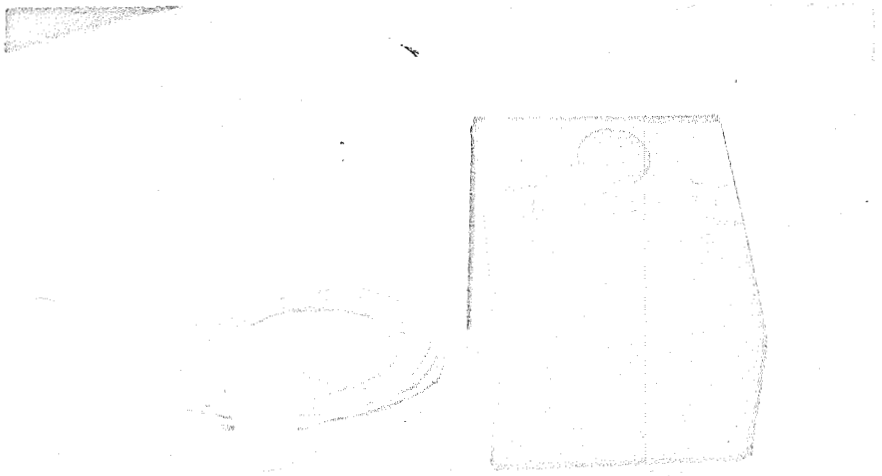


FIGURE 12: Newborn Infant Respiration Monitor

pulsating signal to the nurse's station usually located outside of the nursery. Interruption of the signal indicates the infant is having respiratory distress. In this connection, the Problem Originator preferred a continuous signal to indicate the occurrence of continuing respiration rather than an automatic alarm feature to announce the onset of apnea. The Problem Originator indicated that the quality of the continuous tone transmitted can, to the experienced ear, provide valuable information concerning the infant's respiration.

Breathing (Apnea) Monitor. To ease breathing in infants, comatose children, or adult patients, surgical implantation of a tracheotomy tube in the windpipe is sometimes required. If the tube is clogged and cuts off breathing, brain damage or death can result within 2 to 4 minutes. Use of the tube ordinarily requires a nurse constantly to check the tube and take immediate corrective action if necessary. Integrated circuitry, designed and fabricated for aerospace use by NASA's Ames Research Center, has been incorporated in a small device to monitor the temperature of air passing through the tube, and to actuate an audible/visible alarm within 20 seconds of any change (Figure 13). The alarm can be seen or heard at the nurse's station, or in another room if the patient is at home.

The breathing monitor is based on an automatic airflow surveillance system that was developed by NASA scientists. It has a temperature sensor/FM transmitter which is attached directly to the tracheotomy tube so that the inspired and expired air flows directly over a thermistor temperature sensor. Changes in the airflow temperature produce changes in the sensor resistance. An FM receiver records the respiration signal which in turn triggers the alarm system if required. The voltage changes caused by respiration are amplified and actuate an electronic switch. The switch provides a reset pulse for each respiratory cycle that is of sufficient length, which is determined by setting the amplifier gain control. The reset pulse discharges the capacitor which serves as the timing element of the alarm control. If the capacitor does not receive a reset pulse for a preselected time (arbitrarily chosen as 10 seconds), an alarm control actuates an audible/visual alarm. The device, fabricated at NASA's Ames Research Center, is on loan to the Institute for Rehabilitative Medicine in New York for clinical evaluation.

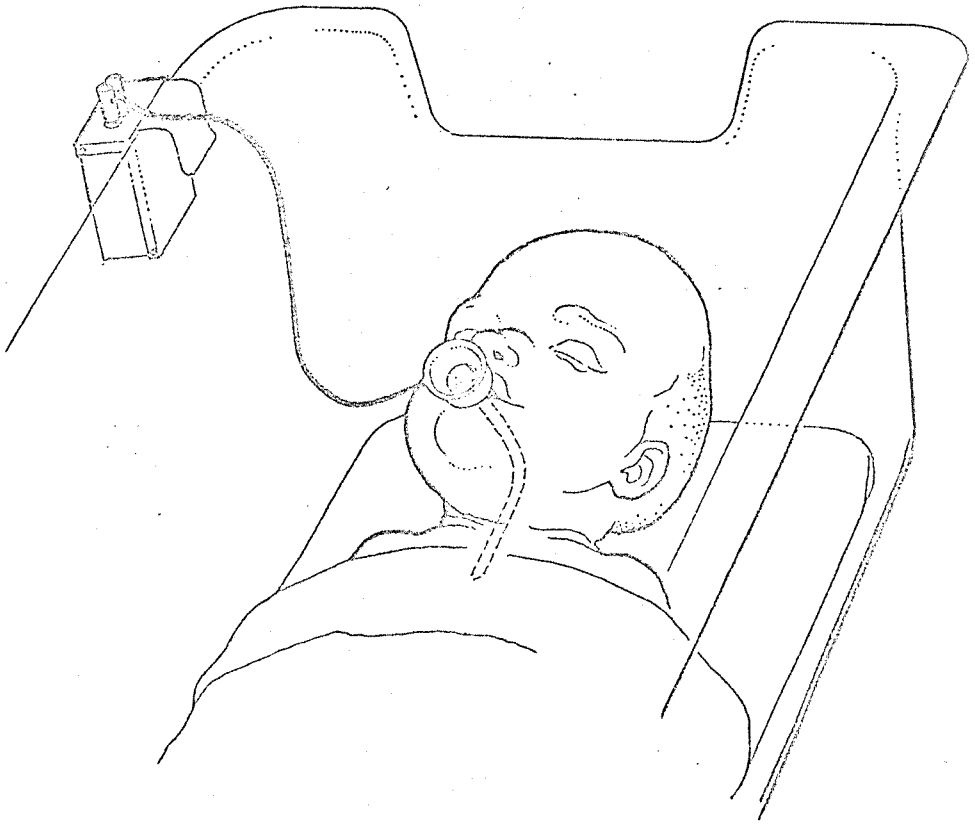
Measurement of Respiratory Function of Free Moving Children. Respiratory diseases are the major cause of illness in children from infancy through adolescence. Some of the more serious respiratory diseases are asthma, cystic fibrosis, and bronchitis. Much research is presently being conducted in causes, diagnoses, and cures of respiratory diseases.

One valuable index for diagnosing lung disease in children is their respiratory rate while engaged in quiet play. If this rate is studied for the same patient over a period of months, much information can be gained about the condition and changes in condition of the patient's lungs. Respiration rate is important because it is directly related to lungs; the body will adjust to the disease by breathing more shallowly and more rapidly. In the case of asthma, a disease which restricts the airflow, the patient will breathe more slowly and more deeply. Thus, respiratory rate is an important parameter in the diagnosis of lung disease.

The respiratory patients range in age from infancy to adolescence, and the monitoring was to occur in a hospital clinic. It was necessary that the

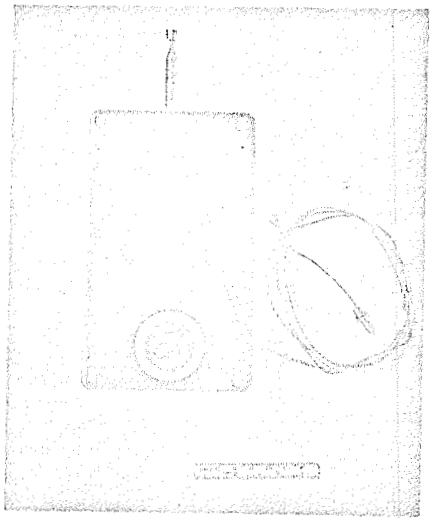
The Apnea Monitor

Size of apnea monitor components in relation to a newborn infant



Sketch showing the apnea monitor in place. Infants with whom the device will be used are generally so critically ill that they are placed in isolettes and do not require restraining arm straps to prevent removal of the monitor

Figure 13. Infant Apnea Monitor



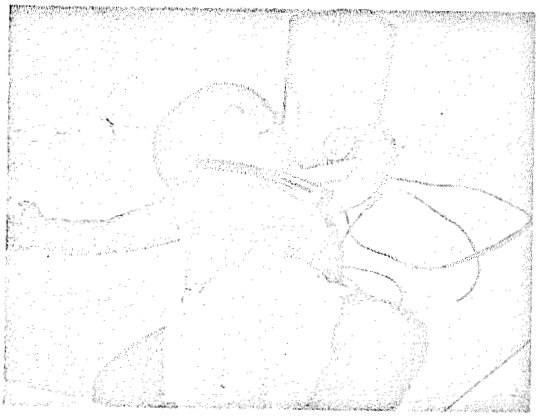


FIGURE 13: Infant Apnea Monitor

rate measurement method would not encumber the child so that he would be free to engage in quiet play. It was also desired that the data would be transmitted to signal processing equipment by a small unit attached to the child. The respiration rates ranged from 12-80 breaths per minute, and precision and accuracy of 0.1 breaths per minute was required.

When approached with this problem by a physician at a Southern medical school, the Research Triangle Institute Biomedical Application Team contacted the Manned Spacecraft Center (MSC). Manned Spacecraft Center personnel suggested the use of the Gemini impedance pneumograph (ZPN) for respiratory monitoring. The Team then discussed this particular problem with an MSC engineer and learned that the equipment was still available. The impedance pneumograph was designed by NASA to measure respiration rate and respiratory volume during a manned space flight. Although the unit had been slightly modified for the Apollo missions, the Gemini equipment appeared capable of solving this problem. The Team performed a search of the commercial literature and determined that, although certain commercial impedance pneumography equipment was available, none of the equipment was as small as the NASA equipment.

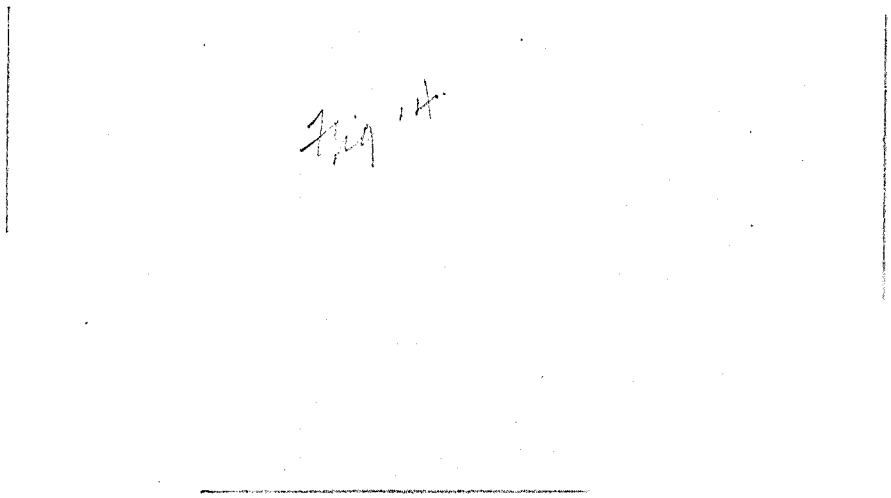
This approach was discussed with the Problem Originator, and it was decided that the NASA ZPN would be a useful approach to the problem. The first step in this effort was to obtain the Gemini hardware to test the suitability of the equipment. When these tests proved satisfactory, it was decided to implement the telemetry portion of the problem with a piece of commercial telemetry equipment. During the preliminary tests it was determined that not only was respiration rate information available, but also the clean waveforms produced by the impedance pneumograph allowed both inspiratory and expiratory times to be determined.

At first, the impedance pneumograph was mated with a commercial telemetry system in a breadboard model. Initial tests on this system allowed the subject to range up to 40 feet from the antenna, and a multiple antennae system was installed which allowed the children to roam freely throughout the clinic area. The unit has now been packaged into a small final unit that will facilitate clinical use (Figure 14).

This application of technology will enable the Problem Originator to obtain valuable clinical information on the respiratory rates of children who are moving freely and unimpaired in a quiet play environment. This information can be used both for diagnostic purposes and for obtaining baseline information on respiratory rates of small children. It is believed that baseline information at the present time is inaccurate because of the fact that the act of taking the respiratory rate modifies involuntary respiration. Thus, both general clinical information and specific diagnostic information can be obtained because of this application. The Problem Originator intends to publish the results from his experiments so that they disseminate to the medical community.

Lung Sound Detection. A method for studying respiratory diseases in children utilizes a technique developed originally to analyze sounds of aircraft engines.

As previously stated, the major cause of illness in children from infancy through adolescence is respiratory disease of which the serious forms include



Allows a physician to record a patient's respiratory rate and inspiratory and expiratory times while permitting the patient to move about freely and unimpaired.

Figure 14. Impedance Pneumograph Signal Conditioner

asthma, cystic fibrosis, and bronchitis. Significant research is being conducted both in the causes and cures of respiratory diseases and in better methods of diagnosis of the diseases.

One useful and simple method to determine whether a portion of the lung is performing properly is to listen to the sounds made by airflow. Usually this is done with a stethoscope, but only one section of the lung can be heard at a time. To compare sections of the lung, it would be useful to be able to compare the sounds generated by a section of the lung with the sounds generated by the symmetrical counterpart in the other lung.

The basic problem is to detect the sounds from two sections of the chest wall by microphones and display the sounds graphically. Comparison will be made on the amplitude, frequency, and time interval between appearance of the two sounds. The frequencies of interest are 50 to 15,000 Hz. Breathing rates normally are 25 breaths/minute, although a range of 12 to 80 may occur. The amplitude of the sounds of interest is not known. Measurements will be made on children from infancy to adolescence in a hospital clinic.

In the basic description of the problem, the Problem Originator desired a strip chart recorder and microphone combination. However, the Team advised him that far more information could be gained by going to spectral analysis such as had been used in analyzing aircraft engines. A difficulty arises in spectral analysis in that real time spectral analysis is required because of the rapidly changing information in lung sounds. Thus a simple scanning filter spectral analysis technique was insufficient because of the time response required. A computer search of the NASA data bank revealed that NASA had done considerable work in spectral analysis--particularly as pertains to aircraft engines and vibration for vibration testing of spacecraft. The Team proposed

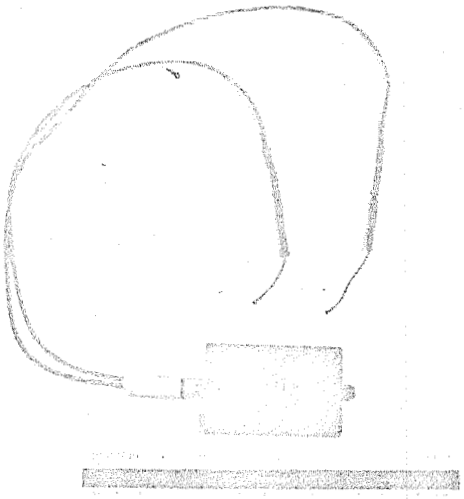


FIGURE 14: Impedance Pneumograph Signal Conditioner

to the physician a system, shown in Figure 15, composed of a microphone, amplifier, and envelope detector which could be fed to a dual-channel strip chart recorder. This dual-channel system would allow time delay measurement for respiratory sounds between similar lobes. In addition, the output of the amplifier could be fed into a spectral analyzer similar to that used in aerospace applications.

The NASA contractor who supplies the spectral analysis equipment is presently discussing a joint investigation with the physician on a spectral analyzer specifically for respiratory analysis. The contractor has agreed to furnish the equipment at a fraction of the normal cost; in return, the physician will provide the medical consultation necessary to develop this new product.

The Team feels that this significant technology application will result in a new diagnostic tool of particular importance in the pediatric field for detection of asthma, cystic fibrosis, and bronchitis.

Tidal Volume Measurements in Respiration Studies Improved by Venturi Transducer. Studies for definition and diagnosis of emphysema volume (volume of air inhaled and exhaled) in conjunction with other physiological parameters. In his investigations, the medical researcher exercises his subjects while attempting to measure their tidal volume with a high-resistance transducer (pneumotachograph). The combined effects of the condition of the patients and a high-resistance transducer drastically increased the respiration work load so that experiments were terminated. The investigator's overall goal was to acquire a resistance-free instrument that would automatically measure tidal volume. His immediate goal was to develop a resistance-free airflow transducer that would enable him to continue his research.

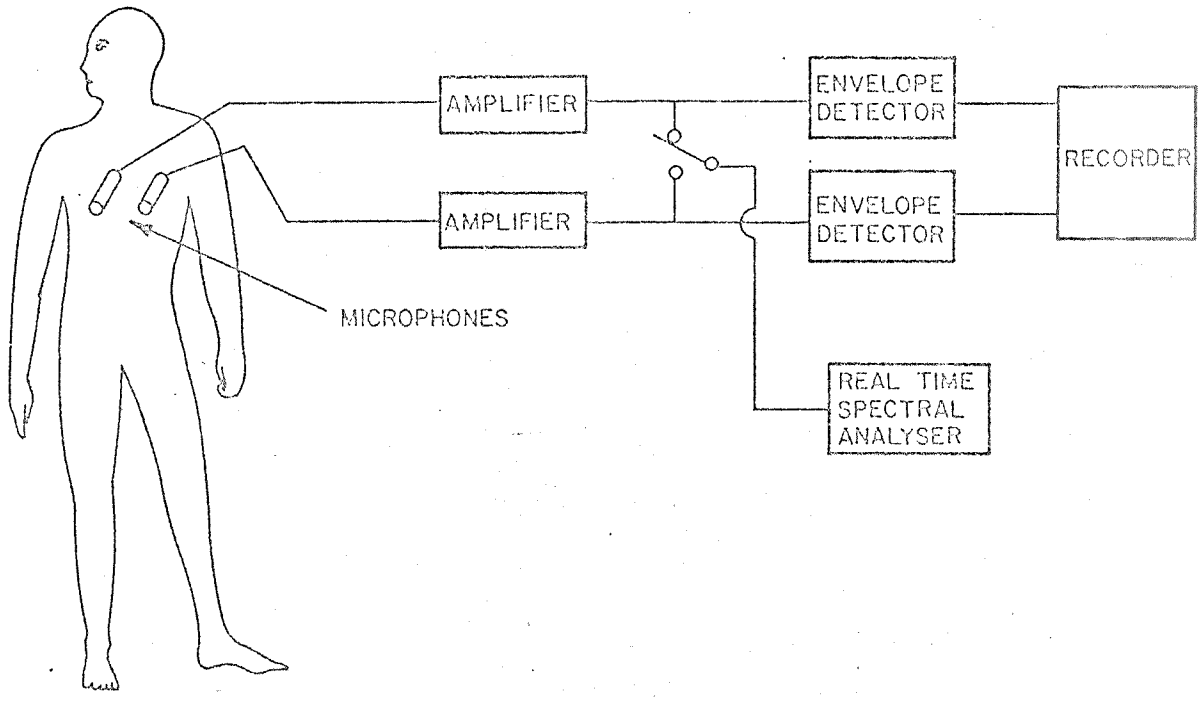


Figure 15. Block Diagram of Lung Sound Analysis System

The Southwest Research Institute Biomedical Application Team provided a solution for both problems based on an article from the NASA Data Bank. This paper, entitled "Tidal Volume Air Measurement," describes an automatic monitor which incorporates a small stainless steel venturi transducer that is obstruction free. It provides a solution to the air resistance problem and it is automatically operated. The researcher plans to fabricate a prototype venturi from glass, increase its dimensions for human use, and incorporate a skin diver's snorkle mouthpiece. The venturi assembly will be used and calibrated as described in the paper retrieved from the NASA Data Bank.

Aerospace Valve for Urinary Control. Certain injuries and diseases cause the loss of voluntary control of the urinary function. In addition to obvious social and hygienic implications, the inability to control urine flow can result in kidney tissue deterioration, infection, and in some cases, kidney damage and death. Attempts to overcome this condition, by using electrical stimulation of the flow-controlling muscles have not been wholly successful because of insufficient muscle response and painful bladder pressure.

A medical researcher treating paraplegics found that there was a need for a simple, reliable, and totally implantable urethral valve which could be easily controlled by the patient. A NASA engineer suggested that a valve similar to the one used in manometer tubes might solve the problem. This valve has been included in the design of an implantable control system. This system will enable the patient to mechanically control urination by applying pressure to a small air-filled bulb located under the skin. Biocompatible materials such as silastic normally used for long-term implants were unsuitable as they react adversely to continuous exposure to urine. A material has been found by the NASA Applications Engineering Project and preliminary tests indicate it is biocompatible and capable of withstanding constant exposure to urine. Difficulties were encountered in fabricating tubing and bulbs of the material but these techniques have been mastered. Five prototype urinary control systems (Figure 16) have been fabricated.

These prototypes will be implanted in dogs to determine if there are any unfavorable long-term interactions between body tissue, the tubing and valve material, and urine. If the prototypes prove satisfactory, the design would be inexpensive to manufacture and could benefit as many as 15,000 patients per year.

The pressure bulb controlled valve may also be useful as a drainage valve for leg bag urinals. Many spinal cord injury patients, who often must wear a leg bag urinal, lack the muscular coordination necessary to open and close a rotary valve to drain their urinal. Their dependence on others to perform this task could be reduced by using a pressure bulb controlled valve to control drainage. As the ability to make a fist and to push on an object are some of the few controlled muscular actions these patients can do, the bulb-controlled valve would appear to be an ideal solution to the problem.

Liquid Flowmeter for Use in Kidney Research. A liquid flowmeter, developed by a NASA contractor may be used to measure urine flow in human ureters.

To understand kidney diseases requires an improved understanding of the total urological system. In the urological system, the ureters are the tubes

fig. 16

Complications resulting from the loss of voluntary control of urinary function are the most common cause of death of paraplegic patients. Based on a NASA manometer tube valve, this prototype, consisting of a flow valve, a check valve, and a pressure bulb has been constructed and is being tested. Voluntary pressure applied to the bulb which is also implanted under the skin allows the bladder to drain completely in a normal fashion, thus preventing the development of bladder or kidney infection or the development of pathological high pressures within the urinary system.

Figure 16. Prosthetic Implantable Valve for Urinary Tract

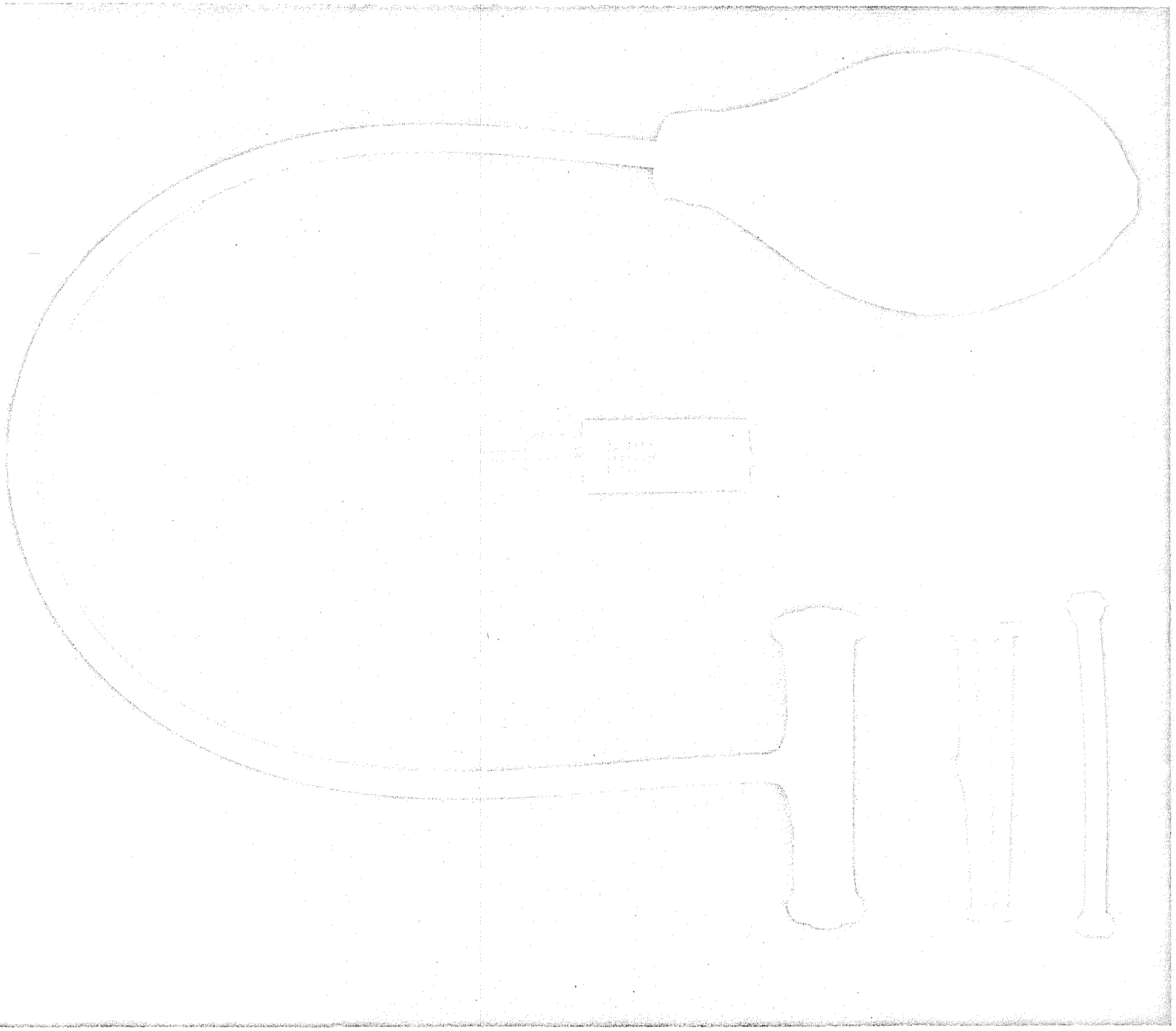


FIGURE 16: Prosthetic Implantable Valve for Urinary Tract

connect each kidney to the bladder. Urine flow measurements in the ureters, to obtain further understanding of urethral physiology, are the subject of a research study at the Washington University. An existing technique for measuring flow in the ureter requires collecting urine samples at definite times to calculate average flow rates. Investigators at the Washington University needed a technique for measuring instantaneous rates of urine flow in the ureter.

After a Problem Statement was submitted to all NASA field centers, the Research Triangle Institute Biomedical Application Team learned of a NASA contractor who was working on a liquid flowmeter utilizing the hot thermistor approach. The NASA contractor and the Washington University investigators are currently arranging for fabrication of this flowmeter.

Scanning Electron Microscope for Analysis of Surface Morphology of Kidney Stones. Research techniques at NASA's Marshall Space Flight Center have been used to extract information on the structure of kidney stones. A researcher at Bowman Gray School of Medicine has been engaged in a long-term study of kidney stones, their occurrence, causes, and related surgical techniques. The overall objective of his research is to prevent the formation of kidney stones in patients. Specifically, he is seeking to understand the mechanisms which cause kidney stones to form in some people and not in others. To this end, he has undertaken a number of research programs and techniques which have yielded much useful information. However, a precise theory for why kidney stones form in certain people and not in others has not yet been clearly established. For example, it appears that concentration of the chemical components in the urine may not be the critical factor because stones form in certain people who have lower concentrations of the chemicals which seem to be the basic ingredients from which urinary calculi are formed. Tiny crystals are formed in the tubules of the kidneys in many people. However, in certain people these tiny crystals grow and form kidney stones. As a result of the researcher's work in this area, he suspects that there may be a difference in the surface structure or in the surface energy between those crystals which grow and form urinary calculi and those which remain in the tubules and do not grow.

A significant portion of the population is affected by kidney stones. Passing kidney stones is an extremely painful process, and those which are not passed can frequently cause severe problems and even necessitate surgical intervention. The researcher is seeking to determine those factors which can control the formation of kidney stones in human beings. In this particular problem, he is seeking a means to examine the surface morphology of renal calculi which will yield more useful information on the surface structure than that presently obtained from light microscope techniques. Basically, a means of examining the surface structure of various kidney stones is desired so as to be able to determine whether or not surface morphology is a factor in kidney stone formation.

As a result of a visit to the Marshall Space Flight Center (MSFC) by one of the Research Triangle Institute Team members, the existence of a very excellent scanning electron microscope facility at MSFC was already known to the Team. The potential usefulness of the scanning electron microscope in performing the surface structure studies which were needed was discussed with Dr.

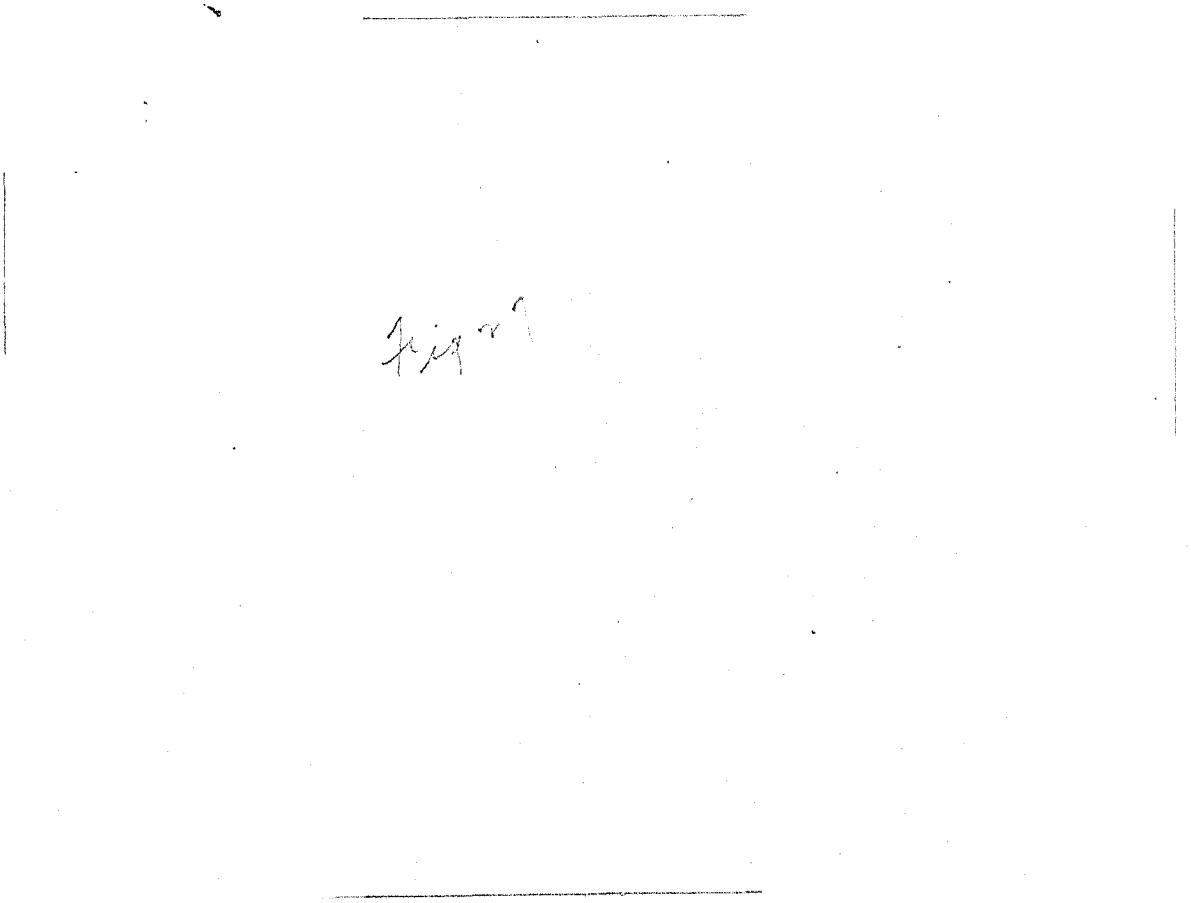


Figure 17. Electron Micrograph of a Kidney Stone

Boyce. Discussions revealed that this technique appeared capable of providing the exact information he required.

The Technology Utilization Office at MSFC made arrangements to use the facility and four samples of representative kidney stones with identification numbers were sent to the scanning electron microscope facility at MSFC. Electron micrographs were desired of the surfaces of the kidney stones and of the cross-sections obtained when the crystals were fractured. This was accomplished by the scanning electron microscope facility at MSFC, and a total of forty scanning electron micrographs were made (one of these is shown in Figure 17).

The immediate benefit of this effort is that the analytical techniques necessary for the researcher to determine the applicability of a theoretical hypothesis which he had formulated has been made available. The researcher did not have available within the School of Medicine the analytical techniques and the instrumentation which were required for the solution of this problem.

The long-range benefits of this application depend upon whether the hypothesis concerning the relationship between surface morphology and kidney stone formation is proved or disproved. If the relationship is indeed established,

FIGURE 17: Electron Micrograph of a Kidney Stone

then significant strides will have been made in the understanding of the formation of kidney stones in human beings. One can foresee that once a fundamental understanding of the mechanisms involved has been delineated, methods to prevent the formation of kidney stones would soon follow.

Rapid Detection of Bacteria in Urine. A neighborhood health clinic serving approximately 25,000 inner city residents has, as one of its principal missions, the delivery of preventive medical care. One part of their program has been to periodically visit residences to measure blood pressure. In addition to a high incidence of hypertension among this population, a high incidence of bacteriuria has been found in those hypertensives who have participated in a more thorough examination. As a result of this observation, the clinic has been looking for a rapid means of making urinary bacteria counts in the field.

Upon contacting the Midwest Research Institute Biomedical Application Team, the clinicians were informed of an instrument developed at the NASA Goddard Spaceflight Center. Based on the presence of ATP (a high energy compound present in all living cells), it utilizes the firefly bioluminescent luciferin-luciferase reaction for the detection and counting of bacteria. The device is basically a semiautomatic photometer which detects the light radiated by the luciferin-luciferase reaction which occurs in the presence of ATP.

This instrument can make the bacterial detection (in urine) in twenty minutes rather than the 3 to 5 days previously required. Having already been tested at the Johns Hopkins Medical School, it was found that the device permits the accurate screening of a large number of patients in much less time. This rapid bacterial identification and diagnosis can forestall serious urinary tract infections and complications while reducing the cost of manpower and numerous chemicals required by older methods. A joint proposal between the neighborhood health clinic and Midwest Research Institute has been prepared and funding arrangements for fabrication of the device are underway.

EEG Helment for Early Detection of Hearing Defects. Based on a system used originally to record changes in the brain waves (EEG) of astronauts and pilots while under gravitational stress, this EEG helmet (Figure 18) is now part of a system to test the hearing abilities of small children by recording their brain waves. Thousands of children classified as mentally retarded are believed to be suffering not from mental retardation, but rather from hearing difficulties which have cut them off from the environmental interaction which is essential to the development of their intellect. If these hearing defects can be identified early in infancy and appropriate remedial measures are taken, then it is possible that many youngsters can be prevented from becoming functional retardates. Thus, the entire system is intended to assist in identifying hearing defects in young children who cannot verbally communicate information regarding whether, and to what degree they hear an auditory stimulus.

Mounted on the helmet are a set of three electrodes, a low noise, high gain amplifier, and a pair of earphones for administering the auditory stimulus. The helmet mounted electrodes have several advantages over the more conventional, individually attached type. No prior scalp preparation is required and, as all three electrodes are simultaneously placed, the time required to prepare a child for testing is significantly reduced. No special electrode paste need be applied to the child's scalp and later removed as in

Fig 18 A

The EEG audiometric helmet in position on the subject. The electrodes can be adjusted to a variety of head sizes, do not require shaving of the head, and do not require use of electrode paste. Used in a hearing testing program, evoked response audiometry uses changes in the brain waves to determine an individual's threshold of hearing. This makes it possible to determine hearing deficiency in infants and young children. By identifying and applying proper treatment to those children with a hearing problem, they may be prevented from becoming functionally retarded.

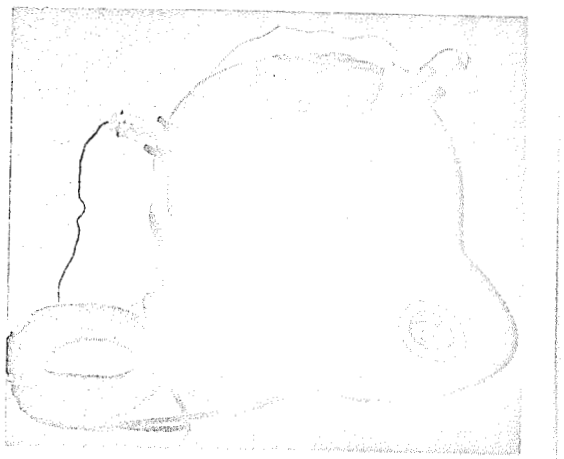
Fig 18 B

The NASA electrodes in place in the helmet. Audiometric signals are administered via the earphones.

Fig 18 C

The NASA EEG electrodes. (Note the threads which permit precise adjustment when placed in the helmet.)

Figure 18. NASA EEG Audiometric Helmet



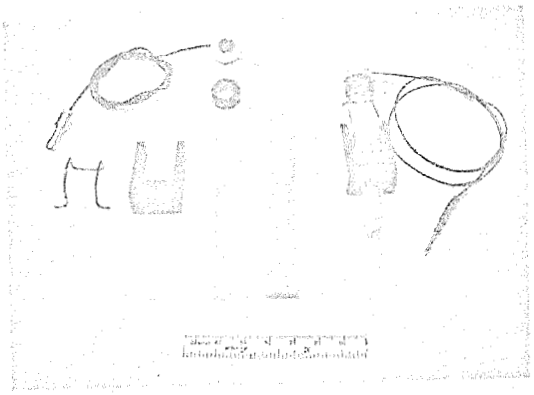


FIGURE 18: NASA EEG Audiometric Helmet

the conventional recording method. The electrodes and leads are held firmly in place by the helmet so the child cannot tear off or dislodge electrodes by a mere swipe of his hand; a problem frequently encountered in the conventional individually attached electrode technique. All of these considerations would be quite valuable in terms of time and cost reduction in a large scale screening program. The low noise amplifier (based on Ames Research Center design) built into the helmet amplifies the signal by a factor of 1000. By reducing the length of the wires carrying very small signals, the possibility of extraneous electrical noise pickup is significantly reduced.

Thus, with this system, auditory signals (tone bursts or clicks) are fed into the helmet via the built-in earphones. If the child "hears" the signal, it is indicated by a change in the brain wave pattern. The child does not have to tell the researcher that he hears. If he does in fact hear, his response will appear in the processed and displayed EEG tracing.

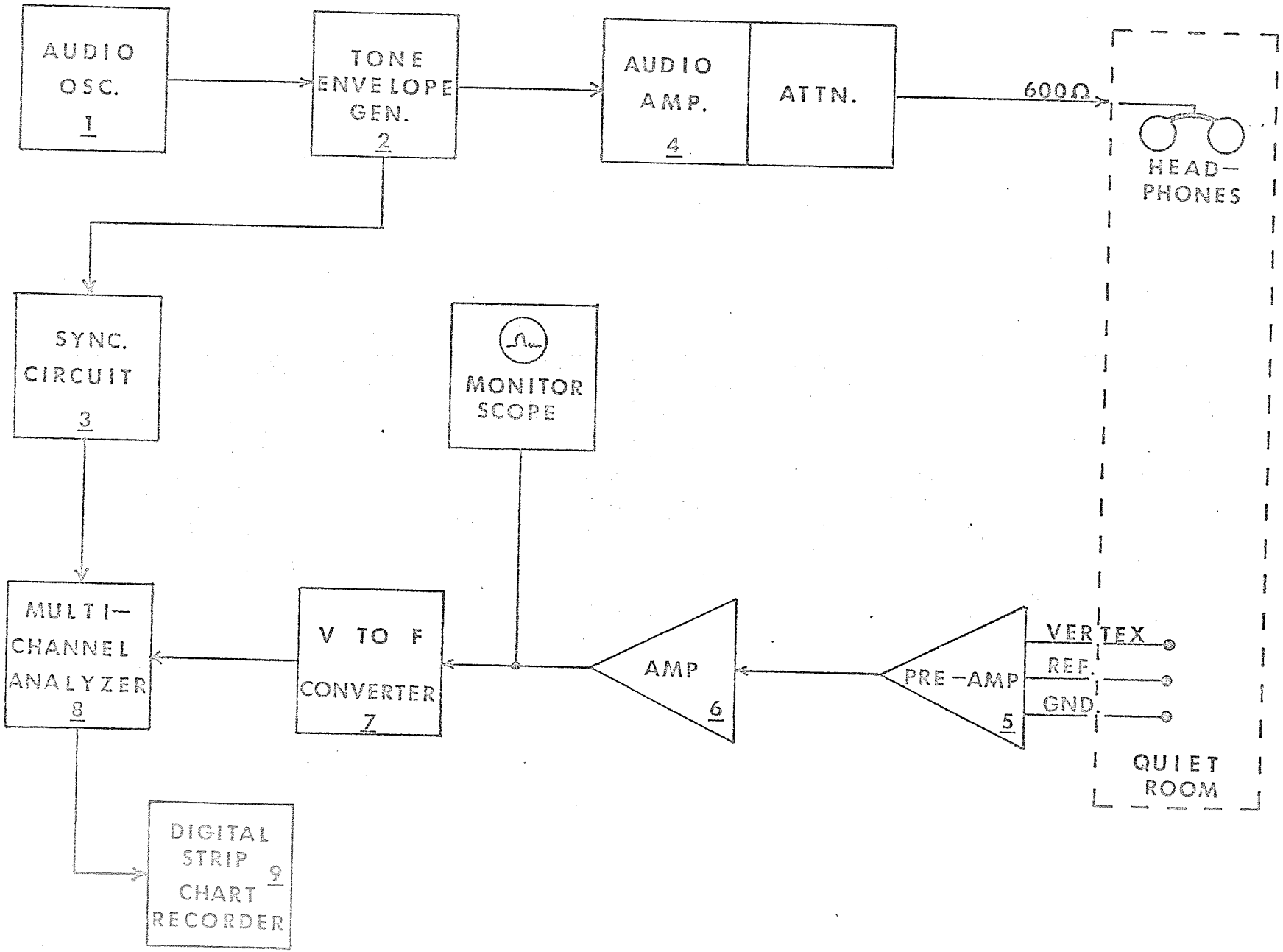
The Southwest Research Institute BATeam, which originally suggested the application of the NASA EEG helmet to this problem, is coordinating a developmental effort with Marshall Space Flight Center's Astronics Laboratory to fabricate an appropriate signal generating and processing unit. The necessary electronics instrumentation required to make this technique readily portable and economically practical will be developed. The block diagram of the total system is shown in Figure 19.

An Objective Measure of Human Motor Activity. A large proportion of critical bed space in hospitals is currently occupied by patients who are receiving psychiatric or psychological treatments in one form or another because of the psychosomatic nature of human illnesses. Researchers at a southwestern medical school are assessing the effects of various mental health treatments. Drugs, psychotherapeutic regimens and controlled environmental conditions are employed during therapy. The Problem Originator believes that objective information concerning elicited motor action or reaction from the patient will contribute significantly to treatment and prognosis for mental illnesses.

A reliable means was needed to objectively and accurately measure and record changes in the patient's motor activity. This overt activity reflects the degree of change in generalized hyperactivity and is recorded as fine and gross voluntary movements, as distinguished from any involuntary, ultrafine, tremor-like movements. The researchers wanted to measure activities such as scratches or fidgets, as well as such activities as pacing or moving about, while a patient is within a therapy enclosure with dimensions of about 15' x 15'. The patient will be alone within the enclosure for possibly extended periods of time, or the patient may have a therapist with him during the early stages of monitoring and treatment.

The patients will be children or young adolescents who can be expected to subject themselves and their environment to relatively rough activities. The required instrumentation must be able to withstand such activity and function accurately throughout the normal and exaggerated motion patterns characteristic of these age groups. It must meet all the prerequisites of safety and must avoid unduly attracting attention to itself or irritating the individual. Hampering or restricting movement must also be avoided since this alone could introduce an uncontrolled variable into the therapeutic situation which could invalidate all or part of the study.

Figure 19. Instrument Block Diagram


AUDIO OSC. 1
TONE ENVELOPE GEN. 2
AUDIO AMP. 4
ATTN.
600Ω
HEAD-PHONES
SYNC. CIRCUIT 3
MONITOR SCOPE
MULTI-CHANNEL ANALYZER 8
V TO F CONVERTER 7
AMP 6
PRE-AMP 5
VERTEX
REF.
GND
QUIET ROOM
DIGITAL STRIP CHART RECORDER 9

The Southwest Research Institute Biomedical Application Team retrieved little of significance from a search of NASA literature on this subject. NASA Tech Brief B68-10315, Gimble Angle Sensor, appeared to have some applicability, but was ruled out when the Problem Originator evaluated the complete technical support package. A television approach tied into a computor also was being considered. A Medical Problem Statement was prepared and approved for dissemination to NASA scientists at the research centers.

Research scientists at the Naval Weapons Center at China Lake, California, responded directly to the Problem Originator. They proposed an infrared technique incorporating a paper readout. The preliminary feasibility testing of the device and recording of movement encouraged the scientists to believe this could solve the problem. The Problem Originator evaluated the concept and was pleased with the potentials it offered. He presently is negotiating to obtain a working model for extensive evaluations, and is confident that this technology will satisfy all of the requirements of the problem.

Testing of Neuropathic Patients. Many people suffer neuromuscular disorders which result in the loss or impairment of muscular control. The cause of these disorders is damage to the nervous system which controls the musculature. One symptom of this disorder is uncontrollable tension and relaxation of muscles.

Modern therapeutic treatment allows many thousands of patients to improve the degree to which they can exercise voluntary control over their muscles and, therefore, to assume a more active and useful role in society. Therapeutic treatment, however, is presently hampered by the difficulty of measuring the improvement that individual patients make during the course of therapy. As an example of a currently employed technique for measuring a patient's progress, the patient is presented with a drawing of a thin-lined geometrical pattern and is asked to trace the pattern with a pencil. From this experiment, one can make a subjective judgment regarding the degree to which a patient is able to control the movement of his hand. It was felt that more quantitative measurement of a patient's progress could lead to refined therapeutic techniques which, in turn, could bring about more rapid and more complete recovery for the many patients suffering from neuromuscular disorders.

In the design of highly reliable aircraft and space systems which are to be operated under direct manual control, the problem of the man-machine interface becomes critical. Scientists at NASA's Langley Research Center (LRC) have been working for several years on the problems of designing flight vehicles which are well-suited for control by a human operator. Of major importance is the understanding of the motor and perceptual characteristics of the human pilot. To measure pilot characteristics such as limb controllability, response time, rate of movement, etc., Langley researchers developed a variety of tests and testing apparatus. This research resulted in a mathematical model of the human pilot.

The Research Triangle Institute Biomedical Application Team learned of this research at Langley and arranged a visit to talk with two of the pioneers in pilot modeling. Upon discussing this problem with the Langley researchers, it became evident that the tests they had devised to determine pilot characteristics had much in common with the requirements for testing patients with motor

disorders. The Team was demonstrated a tracking task given to pilots at Langley. In this case, aircraft pilots were required to track a random disturbance by positioning a joystick in a manner which maintains an oscilloscope trace in the zero position. With this configuration, it was possible to record both pilot response and instantaneous error in tracking random disturbance. Included in the task were model stick and aircraft dynamics. This configuration is illustrated in Figure 20 for a single axis tracking task. The Langley researchers suggested that the stick and aircraft dynamics be removed from the tasks in order to acquire a better measurement of the motor performance of neuromuscular patients.

The LRC tracking task with the suggested modifications as shown in Figure 21 was implemented at RTI, and the Problem Originator visited the Institute to evaluate the technique. A detailed evaluation is expected soon.

Human Voice Analysis. An aerospace technique for improving speech transmission from aircraft is being applied in analyzing speech defects.

Approximately 6 to 7 percent of the population is considered to have either temporary or chronic speech defects. In chronic cases, inadequate understanding of the causes of speech defects hampers treatment. For example, one speech defect is characterized by a pitch that is either too high or too low and can be caused by contact ulcers, polyps, polypoid degeneration, or chronic laryngitis.

Technological impediment exists in the analysis of speech defects because of the inability to precisely quantize characteristics of the human voice. This is further complicated by the fact that many changes in the human voice are easily detected by the ear but are often quite subtle in their spectral density or frequency changes. A number of techniques have been employed in an attempt to quantize the human voice, but to date no technique has been found which permits the therapist to measure changes in the human voice before and after therapy.

Speech consists of a broad fundamental frequency and many harmonics. Small shifts in fundamental frequency and amplitude cause large changes in the human voice. Frequency spectrum analysis must be able to detect fundamental frequencies that range from as low as 50 Hz for low-pitched male voices to more than 400 Hz for high-pitched children's voices. The technique must measure fundamental frequencies to a precision of 1 cycle per second and amplitude to a precision of 1 decibel. The analysis technique must take into account both fundamental frequency and harmonics and their relation to the fundamental frequency. Although not required, real time analysis is desirable.

A computer search of the NASA data bank was conducted and 136 citations were noted. Among this large number, several documents appeared to be of particular significance as they discussed speech analysis and, in particular, fast Fourier transform as applied to speech analysis.

These documents were concerned with determining the spectral differences between several languages and in voice detection from a noisy environment (for example, spacecraft). The techniques discussed in the documents appeared to be directly relevant to the problem of speech therapy, and the Problem Originator expressed strong interest in pursuing this approach. The use of the fast

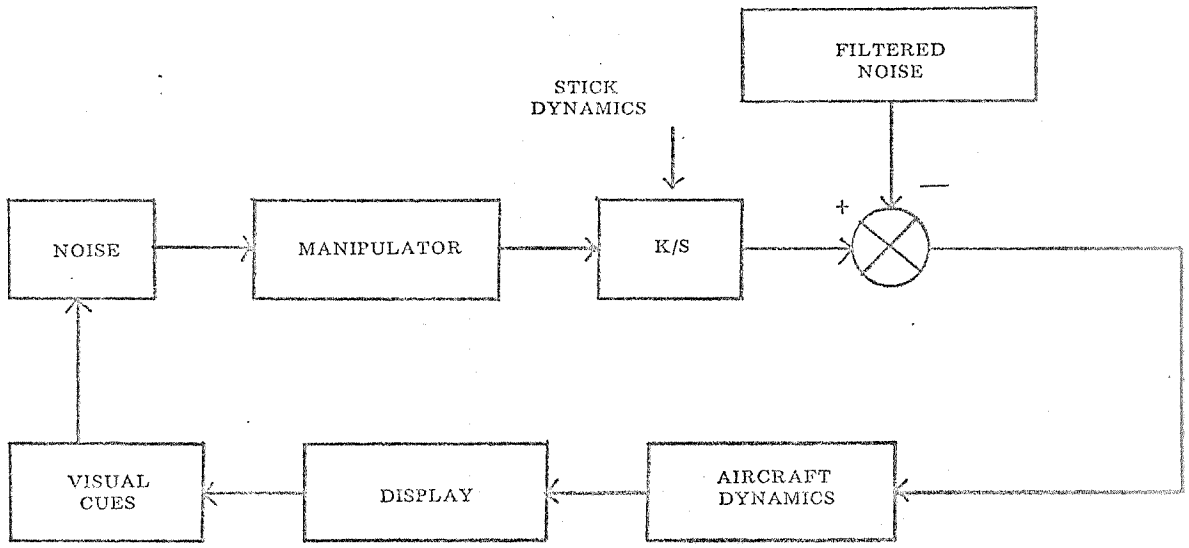


Figure 20. Single Axis LRC Tracking Task

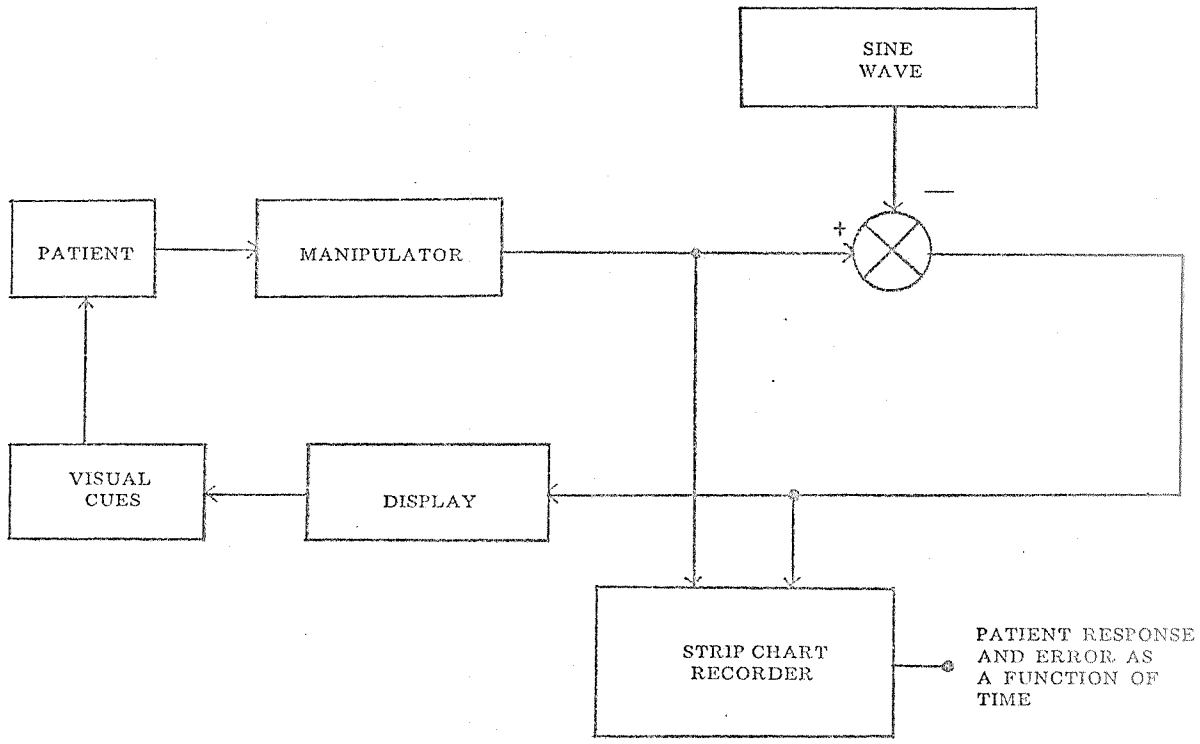


Figure 21. Single Axis Tracking Task for Testing Neuropathic Patients

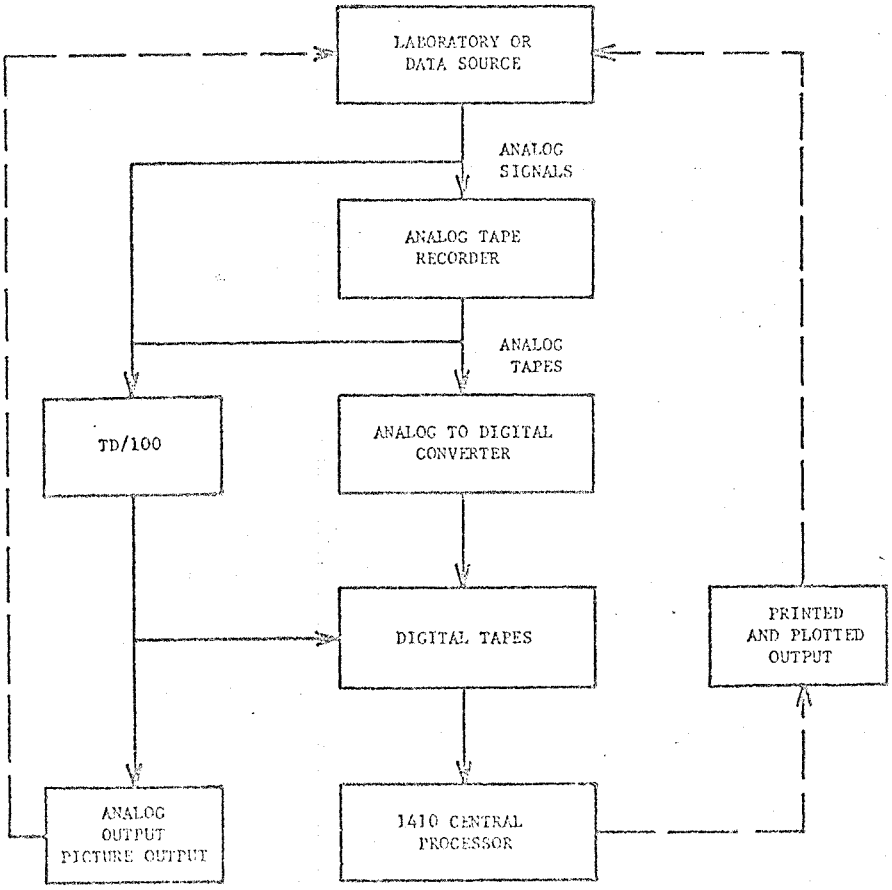


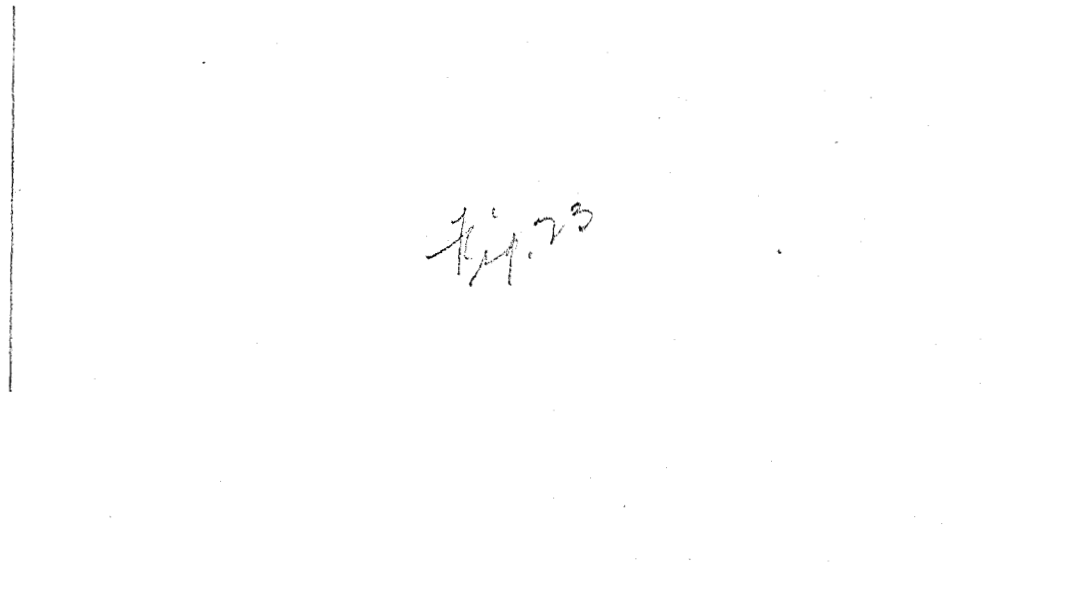
Figure 22. Block Diagram of Voice Analysis System

Fourier transform and a digital computer for analysis was of exceptional interest because of the availability of a computer capable of handling the fast Fourier transform analysis at the Tulane University School of Medicine. This computer was in the Neurology Department, but arrangements were made for its use by the Otolaryngology Department.

At the present time, the fast Fourier transform techniques, outlined in Figure 22, are being implemented on the digital computer for analysis of tape-recorded speech, and comparisons are being made before and after therapy. The initial portion of the study is to establish a baseline of information from which changes can be documented. The physician has indicated that the initial results are favorable, and it is anticipated that an advance in speech therapy will result.

Hydro-John. Persons afflicted with cerebral palsy sometimes have difficulty controlling the processes of urination and defecation. This can be a serious social and psychological problem for the individual, particularly during rehabilitation classes. The use of volunteers in rehabilitation and training makes the problem even more difficult because of the lack of experience and the somewhat objectionable situations that may occur.

A potential solution to this problem was found to be the "Hydro-John" developed by General Electric (GE) for the "Skylab" (Figure 23). Features particularly attractive to the solution of this problem include: self-containment,



Persons affected with cerebral palsy and spinal cord injury patients have difficulty controlling the processes of urination and defecation. The Hydro-John built for the "Skylab" may provide a partial solution in that it is completely self-contained (and this could be built into a wheelchair), and provides for automatic sanitation of the anal area and the containment of objectionable odors.

Figure 23. Hydro-John

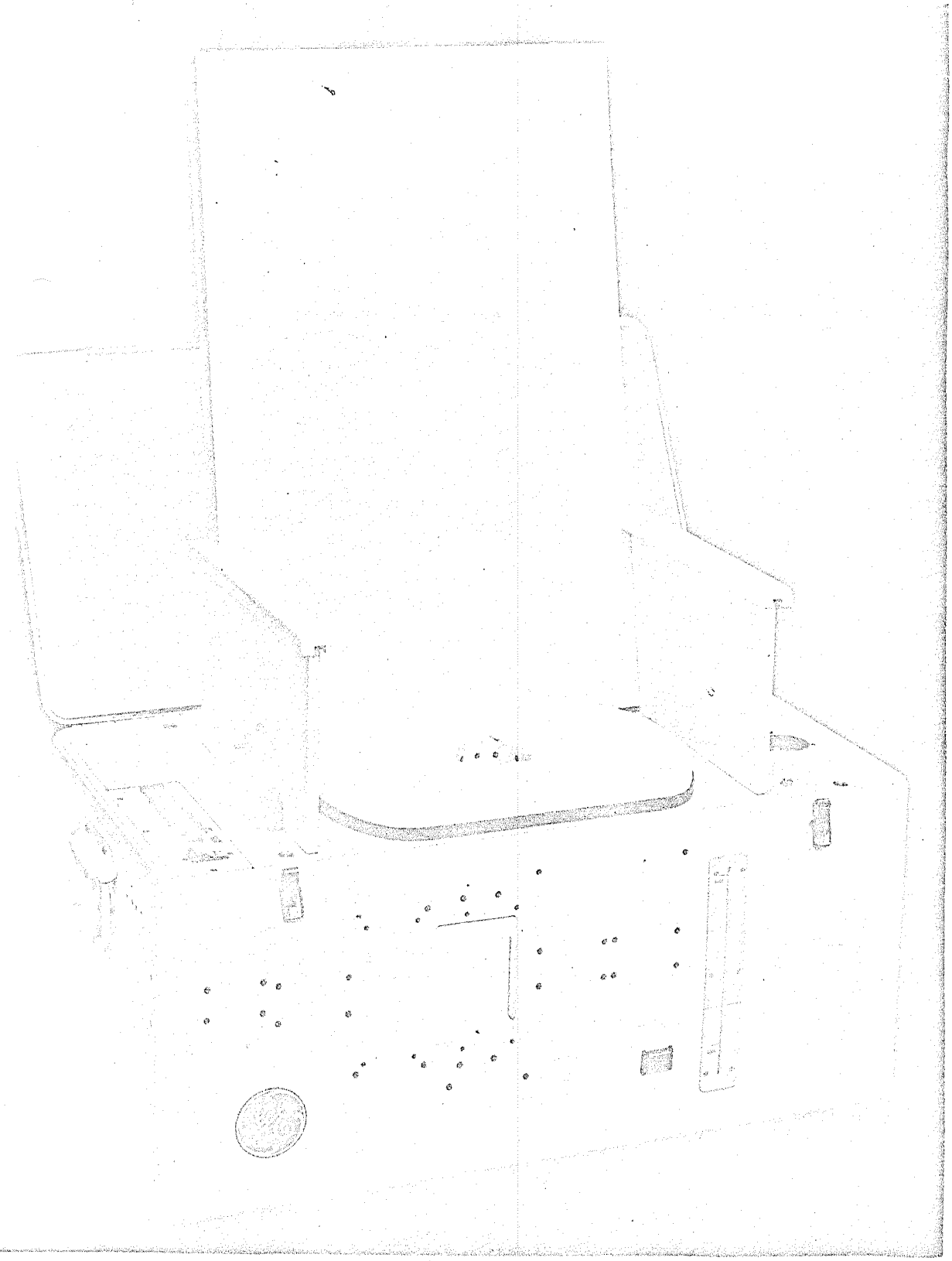


FIGURE 23: Hydro-John

automatic sanitation of the anal area, and the containment of objectionable odors.

The unit has been loaned to the United Cerebral Palsy Association Center and installed. The results so far have been very promising.

The Midwest Research Institute BATeam is drawing up specifications for a small portable urinal that could be mounted underneath the seat of a wheelchair. A number of physician have shown interest in the washing, wiping, and drying seat which seems superior to currently available commercial units and would be of great benefit to stroke and paralysis patients. Discussions with GE are currently underway exploring the construction of additional prototypes and the possibility of product commercialization.

Cleft Palate Airflow Monitor. The determination of the severity of the cleft palate and the effects of corrective surgery can be evaluated by measuring the amount of air passing through the nasal opening during speech. This airflow parameter has been measured, but the equipment used is generally expensive and requires the use of a mask over the patient's nose.

The NASA respiration monitor which uses a thermistor bridge, as described in NASA Tech Brief B68-10438 and supplemental information, will be useful for gross measurements to estimate the amount of air flowing out of the nasal openings. The MRI BATeam fabricated a duplicate model of the NASA respiration monitor and forwarded it to an investigator at the University of Minnesota Dental School for his use. The monitor, in its original configuration, would not measure air volume directly but the investigator has calibrated the device to approximate the volume of airflow. Also, a St. Louis doctor is presently having the device manufactured for him by the St. Louis division of McDonald-Douglas.

Polymethane Foam as a Padding Material. Spinal cord injury patients frequently develop decubitus ulcers caused by continuous pressure applied to weight-bearing points of the body. This is due to a patient's infrequent movement or total immobility. Pressure sores cause much suffering and are difficult and expensive to cure. Their high cost (up to $15,000 per case) is attributed to hospital staff time which must be devoted to the patient, to special medication, surgical correction, and postoperative care.

The Problem Originator presented this problem to the Southwest Research Institute Biomedical Application Team who distributed a Medical Problem Statement to the NASA field centers.

A member of the Ames Research Center staff proposed the NASA developed polymethane foam materials manufactured by Dynamic Systems, Inc. and given the trade name of Temper Foam. This foam (Figure 24) has many unique attributes of combined viscous and elastic properties plus temperature and compression rate sensitivities. It absorbs energy, cushions to a comfortable, flow fitted support and yields high pressure points into soft low pressure uniformity. It can be easily formed while maintaining stiff properties and behaves like rigid foam at low temperatures or elastic foam at high temperatures.

This material appears to satisfy more than the requirements of this problem and several samples were obtained for evaluation by rehabilitation centers

Fig. 24

Decubitus ulcers tend to develop over the bony areas of the body of spinal cord injury patients who experience sensory loss. The average estimated cost for treatment of a decubitus ulcer is $15,000. Researchers have been seeking a cushion material which will prevent formation of these ulcers. A polymethane foam developed for space vehicle seat cushions may result in a significant improvement in bedding for these patients. It may also be used as an improved padding material for wheelchairs and prosthetic or orthotic devices.

Figure 24. Polymethane Foam

under actual conditions. Preliminary reports on the material are most encouraging. The polymethane foam is also being evaluated as a padding material for prosthetic and orthotic devices (braces). These devices are mechanical aids worn to replace a dysfunctional limb. Again preliminary studies appear more promising than any material previously used for this purpose.

On-Line Fabrication of Orthotic Support Devices. Physicians at rehabilitation centers frequently see patients who could benefit immediately (in terms of relief from pain and discomfort) if a rapid means were available for immediate custom fabrication of orthotic devices, such as arch supports. Since most rehabilitation centers do not have in-house fabrication facilities, the usual procedure is to measure the patient for the device and then order it from an appropriate commercial source. This results in loss of a great deal of therapeutic time, since about two weeks usually elapses between order and receipt of the finished item.

The Problem Originator desired to obtain lightweight material--both resilient and tough--which could be readily poured "in-house" to form at least a suitable temporary orthotic support.

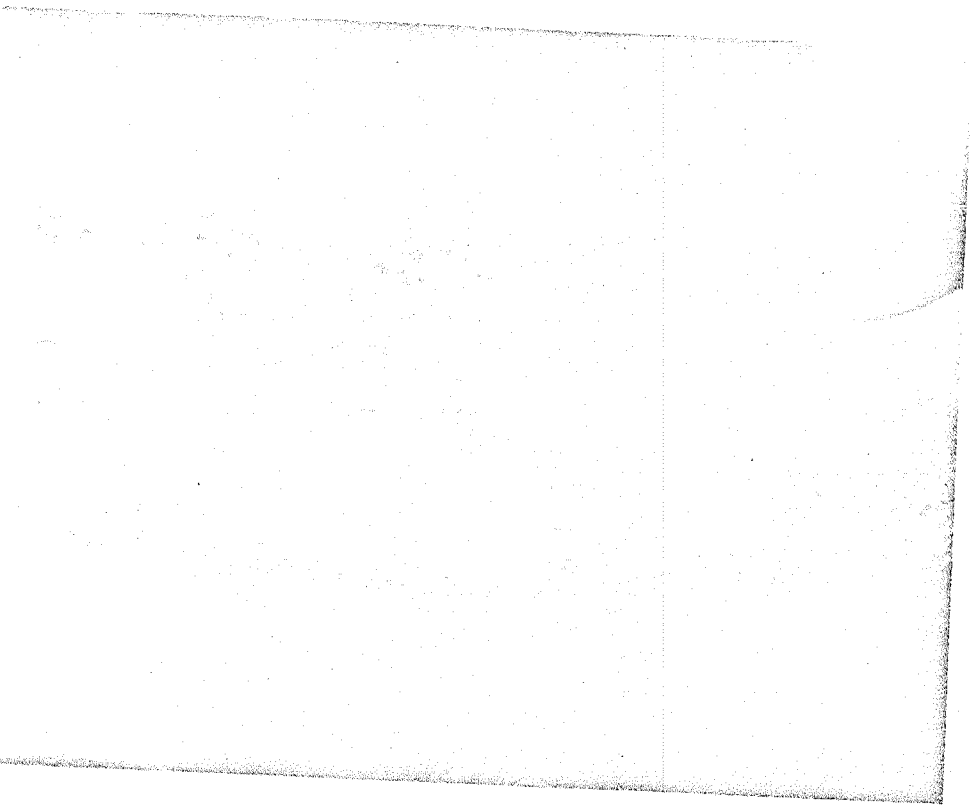


FIGURE 24: Polymethane Foam

Search of the NASA data bank revealed several alternatives: the most promising was the foam-in-place technique developed at Wright Patterson Air Force Base for developing customized, form-fitting helmet liners. The technique (Figure 25) was tried for fabricating orthotic support devices and looks exceedingly promising. Indications are that the technique will prove to be an effective, economical means for providing immediate custom fitted temporary orthotic support aids.

Pressure Sensitive Device for Use in Tongue Operated Control Systems for Assist Devices and Wheelchairs. Severe neuromuscular disabilities are frequently fatal, but survivors are often faced with the prospect of being bedridden. Improved patient care has increased the number of patients who survive severe paralysis. Such patients are greatly limited functionally, hence dependent on society. Dependency relates in part to the extent of disability, and to technological devices and methodology to develop self-sufficiency. Total care for paralytically disable patients is very expensive.

Researchers at the Rancho Los Amigos Hospital have developed a high degree of specialization and competence for implementing a great variety of orthopedic methodologies and devices. They are working with severely disabled neuromuscular patients and amputee patients with the same requirements for care. The development of self-sufficiency for mobility is a major interest.

A wheelchair can be equipped to provide mobility and self-sufficiency. A basic wheelchair has been modified to add the efficiency of electric motors with various switches and attachments. A wheelchair can now be operated forward or backward, can turn, and go up and down inclines or stairs by means of added devices. The researchers are attempting to refine control and operation so that the wheelchair can be used by paralyzed or amputee patients whose use of muscles is limited to those of the eyes, mouth, and head.

Considerable progress has been made in developing control systems for externally-powered orthotic devices. Extra-oral, tongue-operated switch controls provide sequential off-on control of the orthesis, and show promise as a means of providing control.

The Problem Originator requested assistance from BATeam personnel for technology adaptable to incorporation in a reliable, saliva-resistant switch that is small enough to fit the lingual area of the mandible, and sensitive to tongue pressure operation. The BATeam identified a suitable device through a NASA Tech Brief. The device is an insulated-gate field effect transistor, which can perform strain sensing and amplification functions in one hermetically sealed, integral package.

The Problem Originator plans to incorporate the device into a switching unit which will vastly improve on the control devices currently in use. It will, for instance, permit the chair operator to achieve controlled gradual accelerations (and decelerations); a feat not possible with current on-off control systems.

Charging Systems to Prolong Life of Nickel-Cadmium Batteries Used on Prosthetic Devices. NASA conducted research and development to design efficient batteries for powering spaceborne systems. The fruits of these efforts

In place foaming of arch support provides the patient with a custom fitted support device which can be used immediately. Shown here is the arch support foamed to the contour of the foot.

Trimming free foam arch support to fit patient's shoe.

Arch support trimmed and ready for insertion into patient's shoe. The entire process from foaming the arch support to placing it in shoe takes only ten to fifteen minutes.

Temporary arch support in place in shoe, ready for immediate use.

Figure 25. Helmet Liner Foam for Rapid Fabrication of Support Devices

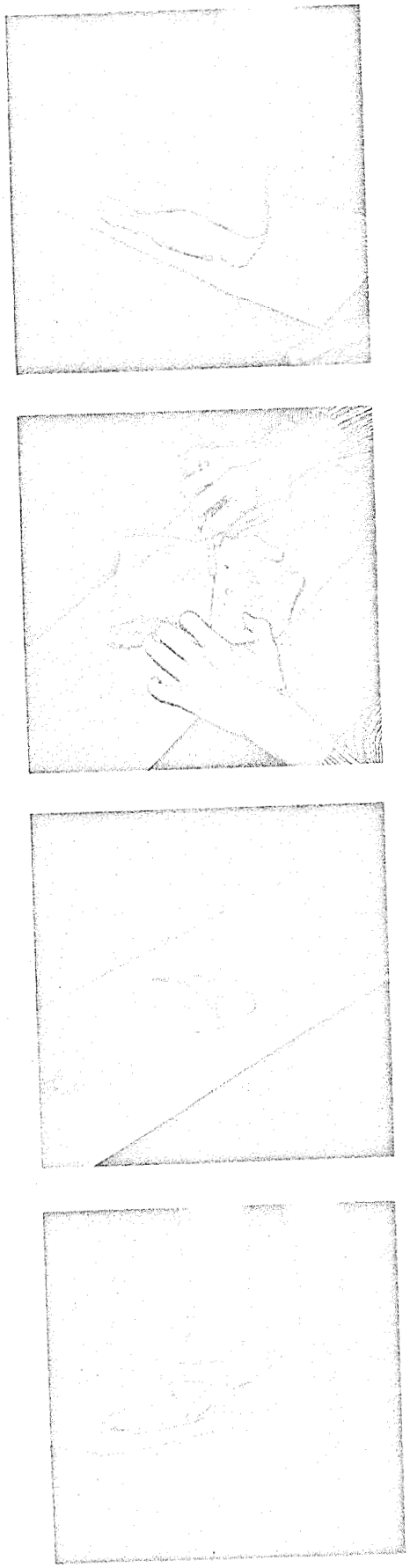


FIGURE 25: Helmet Liner Foam for Rapid Fabrication of Orthotic Support Devices

are being used in development of a motorized prosthetic device. Investigators at the University of Missesota's Department of Rehabilitation and Physical Medicine have developed a prosthetic device which is attached to a patient's crippled arm. An electric motor supplies power to the device's finger support members, enabling the patient to close the fingers with force sufficient to grasp objects. Excessive discharge of the cells, polarity reversal, and diminishing of cell charge capacity were problems encountered with the nickel-cadmium batteries used to power the motor and related circuitry. The investigators needed help to overcome these problems in the nickel-cadmium batteries and prolong their life.

An extensive NASA document on space batteries was obtained by the Midwest Research Institute Biomedical Application Team. It was provided to the investigators who are using the information to improve their ability to use nickel-cadmium batteries.

Measurement of Battery Drain from Powered Prosthetic Device. An electrically powered hand prosthetic device was built at the University of Minnesota. The battery power drain is determined to a large extent by the amount of work that is done. It is important to protect the rechargeable (nickel-cadmium) batteries to prevent damage and short life due to over-discharge. A NASA document titled Mercury Electrochemical Coulometer as a Battery State-of-Charge Indicator describes the use of mercury electrochemical coulometers to measure the condition of secondary rechargeable cells. This type of coulometer is being installed in one of the powered hands. It will provide an indication of the power cells' condition based on the amount of current taken from them.

Telemetry System Permits Dentists to Measure Tooth Pressures. A miniature telemetry system, developed at Ames Research Center, will assist dental researchers in their evaluation of tooth stress under chewing conditions.

The University of Iowa School of Dentistry has been conducting research on the determination and measurement of stress to teeth. Damage and perhaps eventual loss of teeth may occur following corrective dental work unless pressure points are detected and adjustments made to prevent permanent tooth damage. Measurement obtained by this telemetry system will be useful for stress determination in natural teeth that have corrective dental work and will also facilitate adjustments of orthodontic devices.

Used with a commercial transducer, the telemetry unit meets the necessary dentistry requirements. It is self-contained, has an internal power supply, can operate for at least two hours without battery recharge, and can be built to fit under the tongue. The demodulator needed to process the telemetry unit's signal was built by the same researcher after he obtained a detailed description of appropriate NASA-developed circuitry. Both pieces of equipment were located by the Midwest Research Institute Biomedical Application Team through a search of NASA Technical Reports and a review of supplemental information.

Bonding of Metal to Ceramic for Artificial Heart Energy Sources. In attempting to achieve an artificial heart system for man, the guiding objective is not only to prolong life per se but also to provide full rehabilitation to the patient. To the extent that this goal can be realized, the patient should experience a minimum of discomfort and encumbrance. Ideally, the prosthetic

heart system should be totally implantable, i.e., all its parts should be contained within the body. In addition to the many physical and physiological requirements that must be met to realize a compatible, safe, and reliable system for long-term use, the artificial heart must satisfy many stringent design and functional requirements demanded of high performance aerospace systems.

An unanswered problem is that of the type of energy conversion system which will be used to carry out the pumping function of the heart. A stack of piezoelectric disks with interspaced electrodes is a leading candidate for this task. Upon the application of an electric field across the stack, each disk lengthens axially, and the net result is an additive linear movement in the axial direction of the stack. It is this force that will power the blood pump. Various methods of bonding the electrodes to the piezoelectric crystal exist. Use of satisfactory bonding methods can save much time (and occasionally lives) spent on experimenting with unsatisfactory bonding techniques.

The Research Triangle Institute Biomedical Application Team was successful in locating an engineer at NASA's Langley Research Center who had constructed several piezoelectric stacks for preliminary investigations. Two bonding techniques were suggested: one employing epoxy and the other making use of mechanical loading. These techniques were evaluated by the National Heart and Lung Institute (NHLI) and the NHLI contractor who was investigating the piezoelectric stack concept. It was concluded that the epoxy bond appeared promising and that a piezoelectric stack should be constructed for additional evaluation. The NHLI contractor was put in direct contact with the Langley engineer who suggested the epoxy bonding method; following his advice, a piezoelectric stack was fabricated. This stack has good mechanical, as well as electrical, properties and appears to meet the requirements for use as an energy conversion system in the artificial heart.

Interfacing Biochemical Autoanalyzers with a Computer. The Problem Originator wishes to interface several biochemical autoanalyzers used in the Pathology Department of St. Joseph's Hospital with computers to increase the efficiency of specimen analyses. This would help achieve cost savings for laboratory services which could ultimately be passed along to the patient. After defining the problem, the BATeam investigated the computerized diagnostic facilities at the NASA Manned Spacecraft Center (MSC), and found that much of the required technology and computer programs (Figure 26) were available. Arrangements were made for the Problem Originator to attend a seminar at MSC given by Dr. E.C. Moseley concerning the Center's Medical Information Computer Systems (MEDATA). Arrangements were also made for the Problem Originator to meet with Dr. Craig Fischer, head of the MSC Medical Directorate's clinical laboratory. As the result of these meetings, the Problem Originator was confident that if he could obtain the computer programs and related data, he would be able to adapt them for use at St. Joseph's Hospital.

Working through the MSC Technology Utilization Officer, the Southwest Research Institute BATeam arranged to obtain: (1) a listing and magnetic tape containing all MEDATA-related programs now in operations at MSC; (2) technical documentation of these programs; (3) the interface schematics and logic programs and, (4) a document describing the overall system. These have been transmitted to the Problem Originator. Final interfacing is being delayed by a change-over to a new computer.

Fig. 26

Figure 26. The NASA Manned Spacecraft Center's Information Processing System. Many of the Computer Programs Available are of Direct Benefit to the Biomedical Community

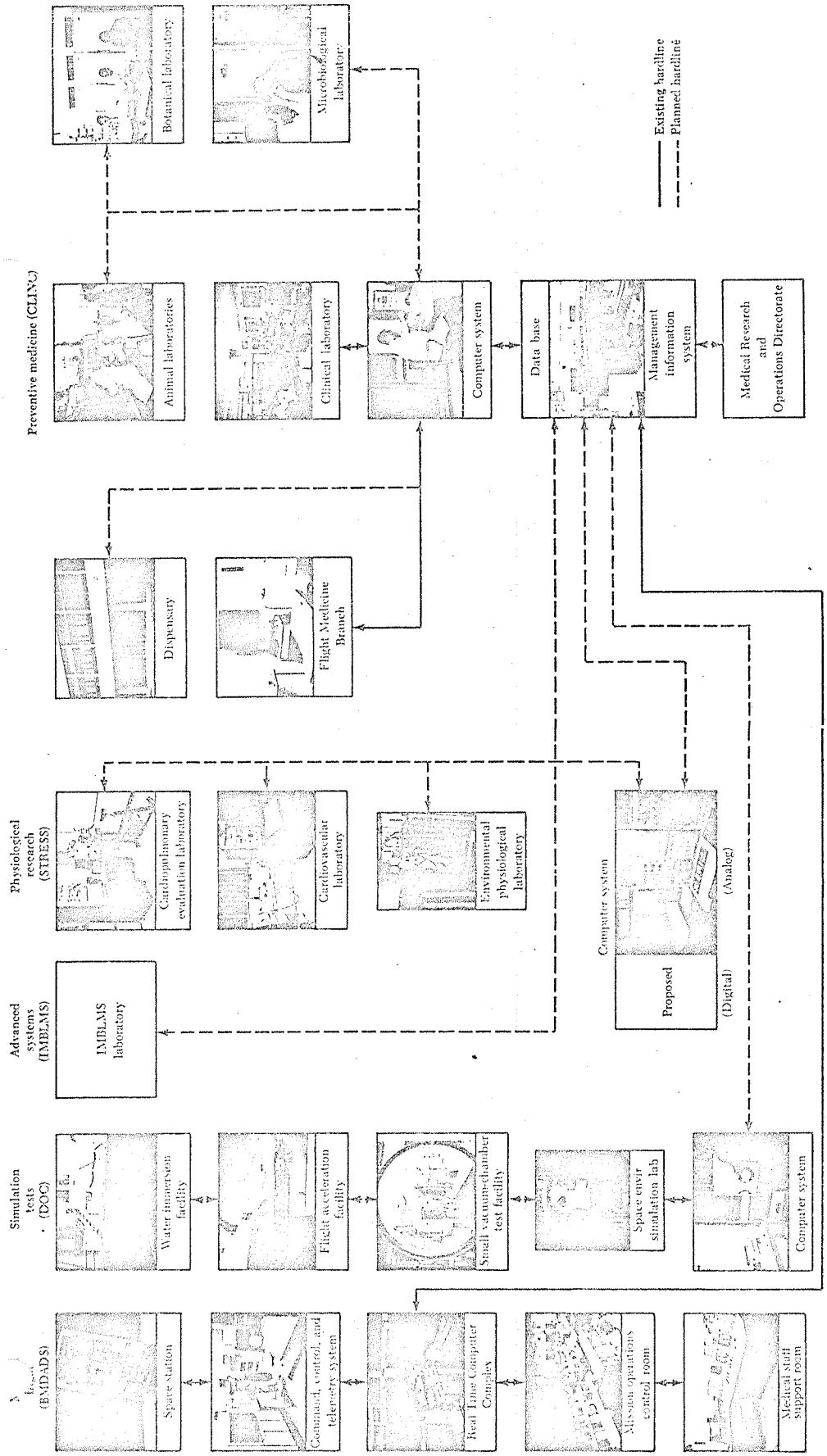


FIGURE 26: NASA Manned Spacecraft Center's Information Processing System

Information Retrieval System for Clinical Records. A southwestern medical facility having 80,000 annual admissions needed a means of retrieving information from its bank of one half million records. The hospital particularly desired access to information which would determine effects of specific medical treatments, enhance disease prevention, and identify trends in medical treatments. The ideal system would permit patient record updating as patients return for treatment. Ultimately, it was desirable to perfect computer analysis techniques for providing guidance in treatment of unusual diseases. The hospital had sophisticated data processing equipment but lacked computer programs to accomplish the desired tasks.

The Southwest Research Institute BATeam arranged a briefing for hospital personnel at the NASA Manned Spacecraft Center Medical Research and Operations Directorate. NASA had originally developed several computer programs for the storage of aerospace medical data and data on the medical history of all of the astronauts. These programs allow for the storage of medical records in a form suitable for retrieval of medical data according to specification and for updating of the medical data bank. Arrangements were made for the hospital to receive program documentation cards and tape, enabling the testing and evaluation of the programs for use in their system.

Management Information Center. The Midwest Research Institute Biomedical Application Team is assisting a midwestern state teaching hospital in the design of a medical education and research management center. The teaching hospital presently runs training programs for nurses (students and in-service), X-ray technicians, practical nurses, medical technologists, aides and orderlies, interns, resident MDs, medical students and pharmacy students. The hospital currently has a library, meeting and training center in the working drawing stage. Several areas of the building have been designated for training purposes. They desire to have at least one room approximately 20 ft x 32 ft equipped with a combination of audio-visual, closed circuit TV, display surfaces, and other devices to allow the most effective training of medical personnel. The hospital has the funds to build and equip this center and plans to open the new facility in 1972.

A plan (Figure 27) was developed based on one of the candidate locations and has been accepted by the hospital administrators. The plan utilized the designs and specifications for display devices, rear projection screens and equipment developed for the Skylab/Space Shuttle Management Center at the Manned Spacecraft Center.

SPECIAL OPPORTUNITIES FOR BIOMEDICAL TECHNOLOGY TRANSFER

Many special and/or unique opportunities for biomedical technology application arise during the course of the Biomedical Application activities sponsored by the Technology Utilization Office. There may be occasions for direct utilization of technology, development of technology relevant to a biomedical problem, or for the highly specialized and creative skills of NASA personnel. Opportunities stem from problems initially defined by the Biomedical Application Teams, NASA groups, other Government agencies, biomedical organizations other than participants in the Program, or qualified individuals needing NASA's assistance. For all technology applications, NASA in-house or contractor capabilities were identified when directly applicable to problems.

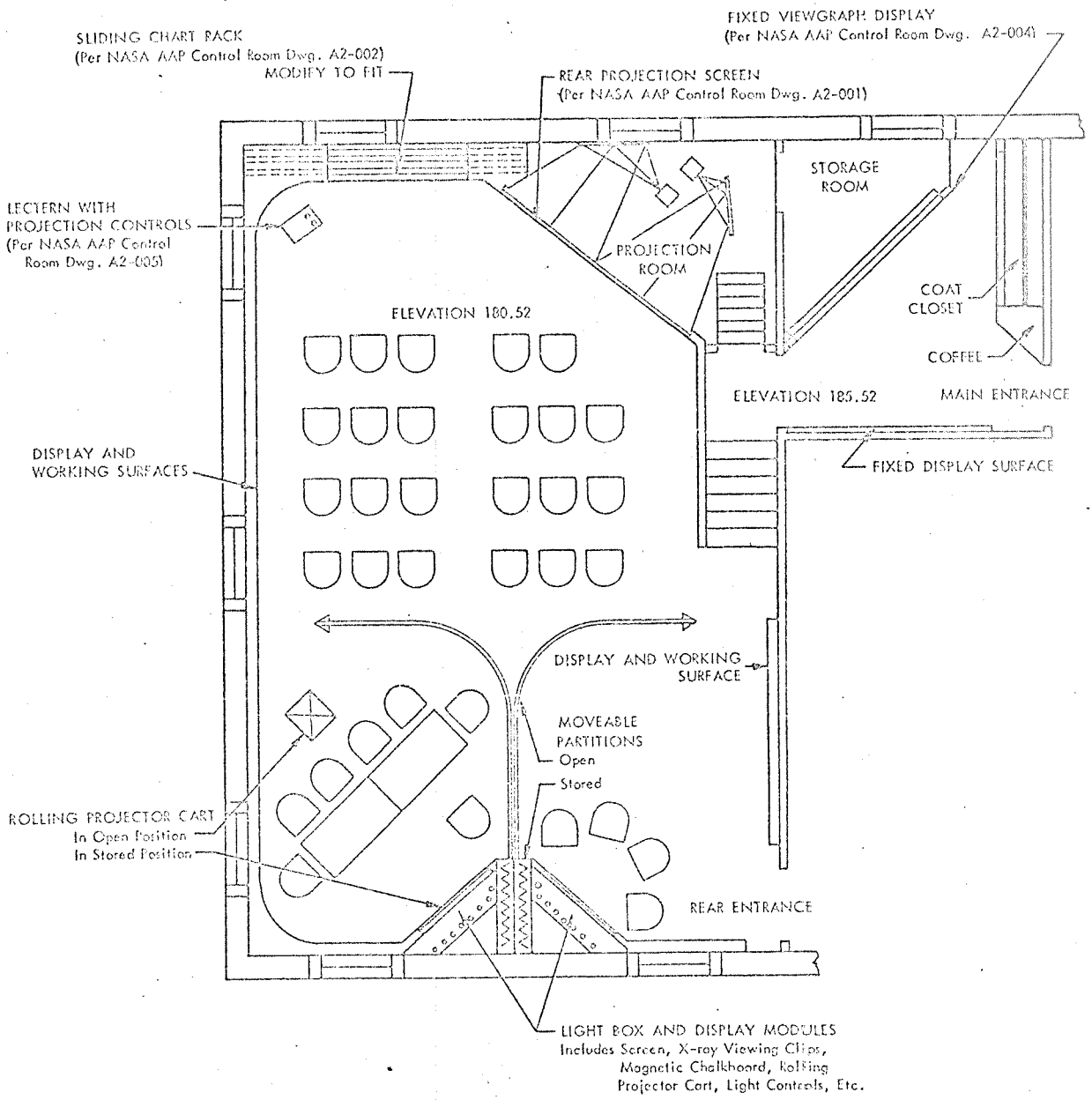


Figure 27. Medical Education and Research Management Center

Application opportunities discussed here were not included in the preceding portions of this section.

Bedside Biomedical Computer. Space Program expertise in microprogramming will prove valuable in developing a small computer for individual patient data storage and analysis. A small individualized computer to process direct and indirect data from a human subject will be developed by investigators at the Massachusetts Institute of Technology (MIT); the bedside biomedical computer will utilize inexpensive, commercially available hardware. NASA will support software development by adapting software from the minicomputers of the Apollo program. A bedside data acquisition/analysis/display unit should help the hospital physician in his diagnoses.

Eyeswitch Operated Wheelchair. Quadriplegics, who are denied the use of both arms and legs, can now use their eyes to operate a motorized wheelchair (Figure 28) with a mechanism called a Sight Switch. The Sight Switch uses sensors mounted on eyeglass frames to start, stop, reverse, and turn a wheelchair by eye movements alone. The device was developed originally so that astronauts could control the flight of their space vehicle while immobilized under high gravitational forces. The switch is now being manufactured by Hayes International Corp. and is undergoing tests at rehabilitation centers. It is estimated that, in addition to more than 100,000 quadriplegics in the U.S., other handicapped persons will benefit from the new mobility achieved from use of the Sight Switch.

Sight Switch Control of Devices to Aid the Handicapped. The Vietnam conflict, plus the increasing incidence of serious automobile accidents on the nation's highways, have resulted in a large number of totally paralyzed (quadriplegic) patients being confined to hospitals and extended care facilities. Depending upon the level of spinal cord injury sustained, some may have limited use of, for example, the fingers. Others, however, cannot even move their little finger or move their head. Obviously, such patients must of necessity depend upon others for everything that is done for them--from feeding and bathing to turning off the lights when they wish to sleep. Rendering the matter even more difficult is that such patients--having no control over their appendages--cannot even activate the call system to summon a nurse for assistance when needed. Subsequently, quadriplegics who survive (and many do not for extended periods) face many long hours at the complete mercy of others.

The Veterans Administration Regional Office in San Antonio had placed a quadriplegic veteran in one of the local nursing homes. The regional office had learned of the NASA Biomedical Application Program's efforts in rehabilitation during a BATeam presentation at a recent state-wide rehabilitation conference. The Team's help was solicited to devise some means for helping the veteran perform such simple functions as turning the page of a book or magazine, or turn on a radio or television set--to help add more meaning to his daily life. The veteran in question, despite the severity of his affliction, remained exceedingly alert and desperately wanted to do something other than continually watch the television set in his room--unable to change the station or turn the set off if he did not care to watch the program. He particularly wanted to be able to read books and magazines. This presented quite a problem, because even with his utmost effort, the individual could not move his arms or hands to activate a control mechanism. The matter was complicated even more by an inability to move his head, a motion that perhaps could have been used to activate a control device.

It appeared to the Team that an ideal solution might well be provided by using the NASA-developed Sight Switch. Accordingly, arrangements were made to obtain one of the sight switches for trial. The Sight Switch (Figure 29) was found to work exceedingly well with a standard mechanical page turner and required but a modest adaptation to put into use. This adaptation involved designing a circuit that could complete the page turning (or other action) sequence--without the patient having to keep his eyes turned towards the switch while the action sequence was underway. With the modification, one brief glance activates the page turning mechanism which completes its cycle automatically, allowing the patient to return his eyes to the normal forward position, thus avoiding eye strain. The eye switch is considered superior to

Fig 2 4

The sight switch, originally developed to permit astronauts to control space vehicle flight under high gravitational force by the movement of their eyes, has been adopted to permit paralyzed patients to control the motion of the wheelchair.

Figure 28. Eyeswitch Operated Wheelchair

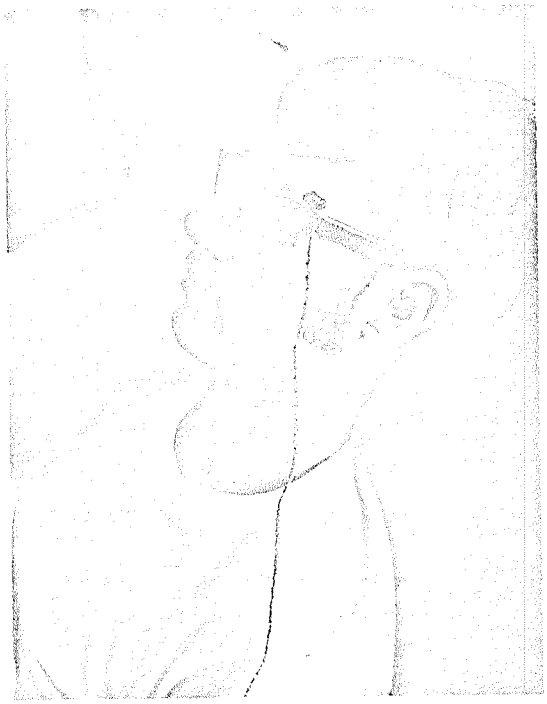
Fig 29 A

The Sight Switch Set is a unique switching device which requires only movement of the eyes to actuate, and provides a "hands free" mode of control. It is small and suitable for mounting on a normal pair of eyeglasses or eyeglass frames. It consists of a low intensity light source and a photodetector to sense variations in reflected light from the area of the eyes, which can then be used to actuate control mechanism.

The NASA switch (with amplifier) interfaced with a mechanical page turner. To turn the page, the paralyzed patient need only turn his eye slightly towards the eye switch. Light reflected from the eye is picked up by the sensing unit built into the switch. In turn this energy, upon amplification, actuates the page turner. This eye operated switch can also be used to control a television set, a radio, the room lights or other devices.

Fig 29 B

Figure 29. The NASA Eye Operated Switch in Place



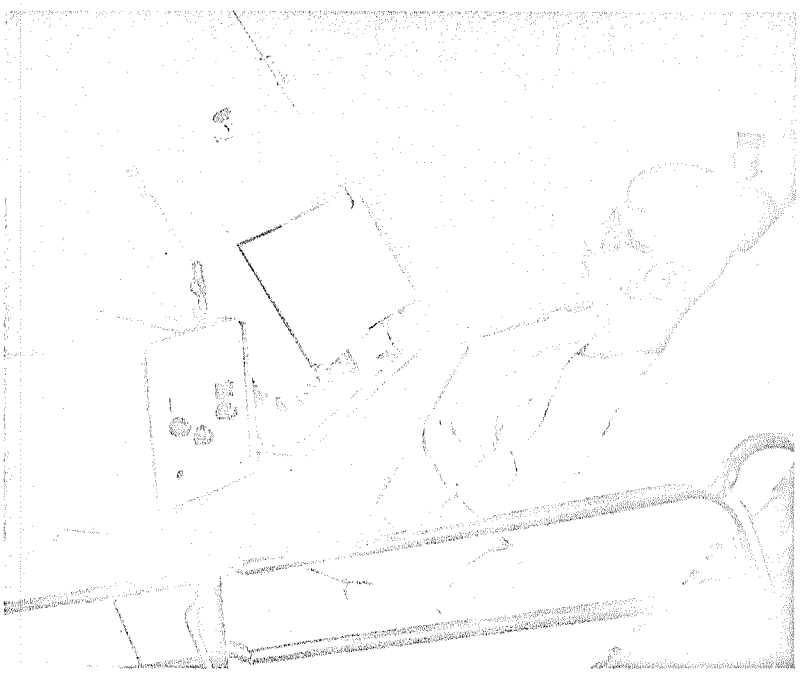


FIGURE 29:

possible alternative control methods, such as intra-oral switches. These are subject to deterioration in the presence of saliva and present problems involving sanitation. A further advantage of the eye switch is that it can, by adding simple logic components, control other functions designed to help give the totally paralyzed patient some measure of control over simple daily activities. These devices can make his day a bit brighter, by permitting him to turn his room lights on or off, call the nurse or attendant, or turn on a special "talking book" phonograph when he tires of reading. The availability of these components are being arranged by the BATeam from Southwest Research Institute. If Team interaction with the Southwestern Bell Telephone Company proves successful in adapting the switch for use in conjunction with a telephone, the patient will be able to call family and friends when he wishes, without the intercession of a nurse to place the call for him.

Some partially paralyzed and amputee patients could utilize orthotic support device assistance for self-care or productive work rehabilitations. Prehension devices are one class of orthotic support devices which have proved to be extremely useful in restoring many functions to this group of handicapped. The prehension devices are becoming increasingly more sophisticated as better means to extend limits of operation are developed and limits of control are refined. The devices have been particularly useful in restoring capabilities for mobility and self-care to patients.

Typically, movements of various muscles and body parts are used to activate the drives and linkages which permit the person to control positioning of the device, or to control the degree of pressure applied. However, there are some patients, particularly those afflicted with disease involving spasticity and muscular tremors who are unable to utilize this method of control. The Problem Originator was seeking an alternative control method which is relatively easy to operate and which is basically an on-off, all-or-nothing activating switch. A switch of this sort is expected to facilitate the training in operation of the orthotic device and to improve the capacity of individuals to use the device for various tasks.

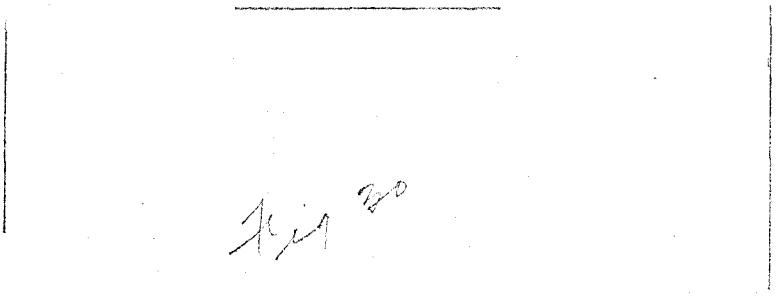
The Southwest Research Institute BATeam personnel considered several alternatives and determined that the sight-operated switch would, again, be a suitable control device. A sight switch has been obtained and is presently being incorporated into the control mechanism of several orthotic devices being fabricated at a rehabilitation center. It is expected that the technology application outlines will have considerable application throughout the nation in hospitals and extended care facilities caring for quadriplegic patients who are unable to perform even simple functions for themselves. For this reason, the Team is preparing special material outlining the technology described for use as appropriate to make others aware of what can be done at a most modest cost to add a great deal of meaning to the daily lives of totally paralyzed patients.

Prosthetic Hand. Servomechanism and electronics technologies were specially developed and applied for NASA in development of a Mechanical Activated Triggered Hand (MATH) for use in teleoperator application by astronauts. The MATH device is now being modified for use in rehabilitation and should permit an amputee to hold and operate power tools such as electric drills. The Technology Utilization Office of the Marshall Space Flight Center is working with

the Rancho Los Amigos Hospital, a rehabilitation center, to utilize this NASA technology to further develop a prosthetic hand.

Biocarbon Implants. High-purity, high-strength forms of carbon, developed through aerospace research, are being used in the fabrication of prosthetic devices. Devices such as bone substitutes, teeth and replacement heart valves are intended for long-term implantation in the human body. Carbon is highly compatible with body fluids and tissues, but until recently, the carbon available was not sufficiently strong for prosthetics use; materials of lesser biocompatibility had to be used.

Preliminary studies show that vitreous carbons developed for aerospace use are sufficiently strong to be fabricated into prosthetic devices (Figure 30) and pure enough to be biocompatible. Vitreous carbon combines strength with chemical inertness. In comparison with other materials used for implantation it is notably light and hard, which will permit low mass implants, and has a low coefficient of linear thermal expansion. Being a pure carbon it is highly resistant to body fluids as it cannot undergo an oxidative attack (corrosion) at body temperature. The advantage of not being of metal is that it should be free of the adverse tissue response such as inflammation, swelling, pain, sepsis, and bony resorption initiated by the release of metallic ions and particles. It also has an advantage over polymers such as acrylic,



High-purity, high-strength forms of vitreous carbon, are prosthetic devices intended for long-term implantation in the human body. Vitreous carbon is the material originally developed as an ablative heat shield for reentering space capsules.

Figure 30. Biocarbon Implants

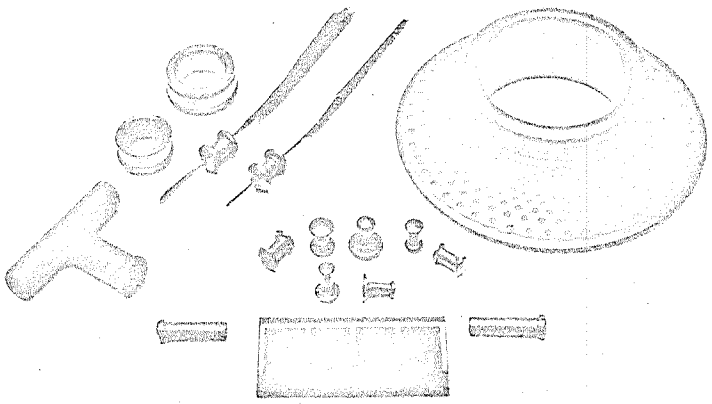


FIGURE 30: Biocarbon Implants

PVC, Teflon, and nylon, in that vitreous carbon contains no impurities or additives, such as stabilizers, antioxidants, and low molecular weight components. With polymers, adverse tissue reactions arise from leaching of these various constituents which can be toxic. Also, though these polymers offer high resistance to industrial chemicals, they are often metabolized by the body, resulting in a loss of strength. Studies to date indicate that vitreous carbon exhibits excellent chemical resistance, high strength and rigidity, and suggest that its use may prove to be a major advance in implantation materials, both for surgical and oral implants. Technology Utilization funds have been made available to the Marshall Space Flight Center for a special project to further develop and test biocarbon materials in cooperation with interested medical specialists.

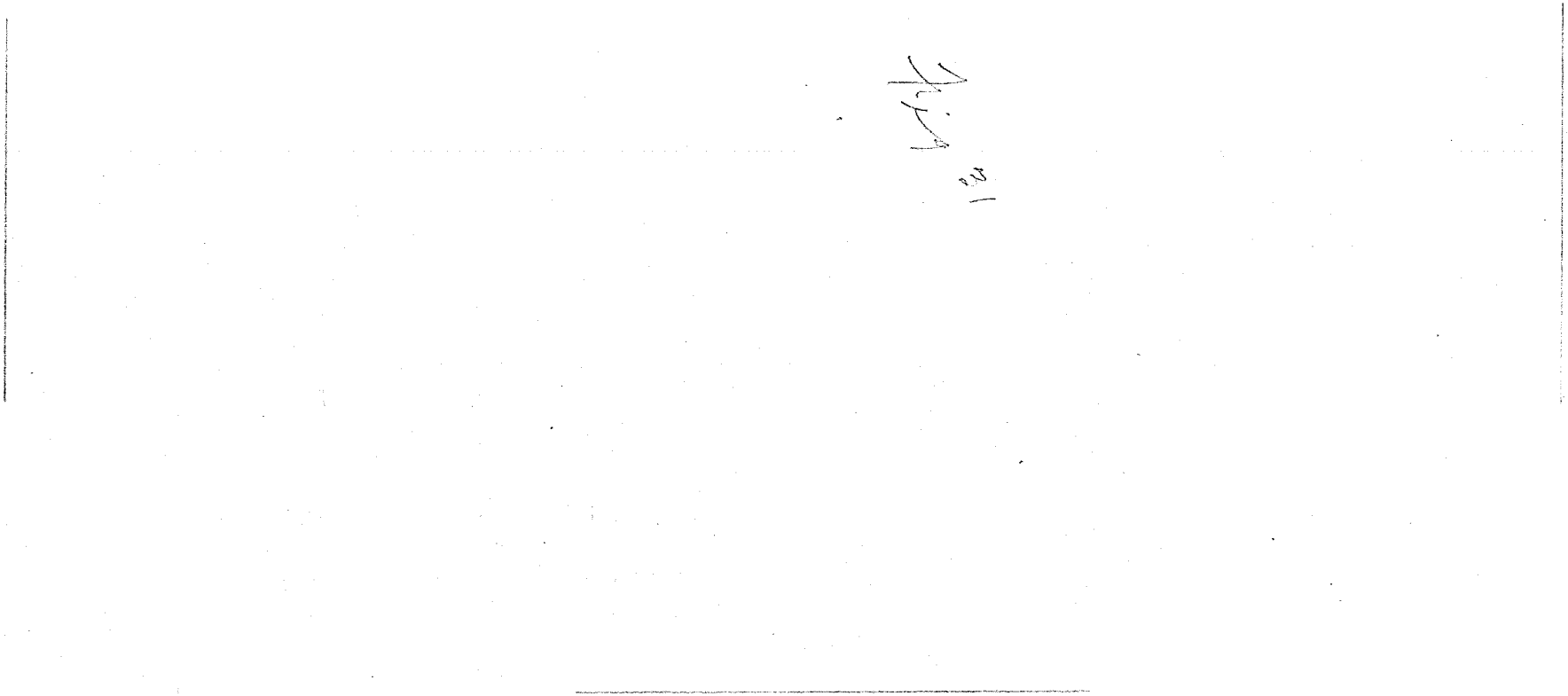
Medical Monitoring Chairs. NASA scientists and engineers have been investigating the use of instrumented chairs as a means of monitoring physiological parameters of astronauts when they are not wearing space suits. The technology may have important ramifications for mass health screening.

This technology was utilized by a NASA contractor to develop a prototype medical monitoring chair. This chair records physiological data such as electrocardiograms, galvanic skin responses, and heart and breath rate from a seated patient without the encumbrance of wires or attached electrodes. The chair is currently on loan to the Alcohol Research Group of the National Institute of Mental Health and is being used to record physiological data with reduced patient anxiety. Further development of the medical monitoring chair will make use of technology resulting from a biomedical engineering summer institute for engineering students sponsored by Goddard Space Flight Center.

Brain Wave Sensor as Diagnosis Aid. A brain wave [electroencephalograph (EEG)] sensor and radio transmitter system, developed for space medical research with test pilots, appears to allow major improvements in diagnosis and treatment of schizophrenic mental patients. Scientists at NASA's Ames Research Center and at Agnews State Hospital, a mental hospital of the California Department of Mental Hygiene, are working together on a system. They are using the radio-sensor system with a computer to develop a new means of diagnosis. The new method is under clinical test on mental patients at Agnews Hospital and has shown good preliminary results.

Modern drugs have made possible tremendous advances in the treatment of many emotionally disturbed individuals. However, there may be a subgroup of schizophrenics for whom nondrug therapy is the treatment of choice. The problem has been to distinguish these individuals from those for whom drugs are most appropriate.

The EEG radio-sensor system (Figure 31) installed in a headset is light and comfortable so that it does not frighten disturbed patients. The diagnostic method is based on research on patient brain wave responses to light stimuli. For diagnosis, the patient is fitted with the comfortable, wire-free headset and seated in a darkened isolation room. He watches light flashes of varying intensity, and his responses are then radioed to the computer for analysis. The technique uses differences between a patient's brain wave responses to a series of light flashes as a way of distinguishing between various types of behavior disorders.



Headpiece with electronics module and battery removed, showing paralleled mastoid electrodes, single vertex electrode, and two temple pads.

Figure 31. Electroencephalograph (EEG) Headpiece

FIGURE 31: Electroencephalograph (EEG) Headpiece

Because of the advantages of this system, doctors now believe they can use it to distinguish between schizophrenics needing immediate large doses of tranquilizing drugs, and those patients who can be treated without drugs.

Past diagnostic methods using brain waves have required the insertion of needle electrodes under the scalp, or shaving of a portion of the scalp for electrode contact. With seriously disturbed schizophrenic patients, these disquieting procedures--required immediately on admission to the hospital--usually have not been possible. The Ames-developed system, however, employs only a headset consisting of a light wire clip fitted with two small electrodes which sense brain waves with no scalp preparation. The headset also carries a tiny battery-powered radio transmitter to broadcast the brain signals to the computer for analysis. Because data is radioed, the absence of wires prevents undue anxiety about shock therapy by some disturbed patients who have either undergone or fear such treatment. The allaying of such fears is important for good, early diagnostic work.

The sensors and radio were developed at Ames for sensing brain waves of pilots riding centrifuges and doing other tests. The 1.22 cubic centimeter, 1.0 milliwatt, Ames developed, high performance transmitter has low internal noise, high sensitivity, and works from a single aspirin-tablet-sized mercury battery. The sensors consist of a silver chloride pellet coated with commercial electrode paste, in contact with a sponge wetted with saline solution. The brain's reaction patterns to the light signals are tiny, brief, and are mingled with the constant massive flow of other brain wave signals. However, a computer program has been developed to filter out these tiny electric signals.

The radio-sensor system has promise for other uses. Patients could wear the headsets in their wards. For patients that are unstable or very acute, moment to moment monitoring and intensive care could be provided similar to intensive care units in general hospitals. Then data on their EEG activity could be radioed to the computer as they engage in a variety of activities, or are presented with different situations.

The NASA Technology Utilization office is funding the fabrication of several additional EEG telemetry headsets and will make them available to qualified users for additional clinical trials.

Anti-g Suit to Control Hemophiliac Bleedings. Hemophilia is a physically and psychologically crippling disease which, according to National Hemophilia Foundation figures, affects more than 60,000 Americans. Afflicted children rarely reach adulthood without disabling joint deformity, contractures, and muscle atrophy due to recurrent hemorrhages following even minor trauma. Maternal over-protection, fear of injury, and recurrent hospitalizations isolate the hemophilic child from his peer groups and often lead to severe psychoneurosis. Employers are reluctant to hire the adult hemophilic because of exaggerated fear of work related injury and excessive sick leave. The cost to society of hospitalizing and supporting these otherwise normal individuals is enormous.

The current treatment of hemophilia consists of the administration of fresh blood or plasma to replace the deficient antihemophilic globulin factor (AHG). The use of AHG concentrates and cryoglobulins gives promise of prevention, but is limited by the development of neutralizing antibodies in 10 percent of the patients, frequency of injections required, and excessive cost

(of AHG). Clearly, any technique or procedure which could prevent or minimize initial bleeding into the muscle or joint (which can sometimes exceed one quart) would be a valuable adjunct in the treatment of hemophilia. Not only would the subsequent crippling effects be reduced, but equally important, the afflicted child or adult could interrelated more normally with his peers.

The use of external body counter pressure, as exemplified in the modern Anti-g Suit, seems ideally applicable for use in the hemophilic. A garment containing a system of inflatable bladders could be worn as an outer coverall which would appeal to a child or as an undergarment under regular clothing. Immediately after a fall or suspected injury, the child could inflate the suit by simply activating a compressed gas cartridge attached to a belt or other easily accessible area. This would result in immediate immobilization of the injured limb, and by forced extension of the joint, a reduction in the size of the joint space into which potential bleeding could occur. The current design concept (Figure 32) provides that the bladders be inflated to prevent pooling of blood in the extremities. Also, the bladders can be removed to permit laundering or interchanging of garments. The use of the Anti-g Suit in clinical medicine is not without precedent. Physicians and researchers at NASA's Ames Research Center and Stanford University Medical Center recently reported a case in which an Anti-g Suit was able to arrest life-threatening hemorrhage in a young woman on whom standard techniques were unsuccessful. The dramatic response in this case prompted the researchers to consider the possible application of the g-suit concept in hemophilia. Their report contains a theoretical discussion of possible mechanisms by which external counter pressure is able to control internal hemorrhage.

The Technology Utilization Office is presently funding the fabrication of a prototype "antihemophilia g-suit" for evaluation on suitable patients in a controlled clinical setting.

Goddard Space Flight Center's Second Annual Summer Institute For Biomedical Research. A unique program, the Summer Institute for Biomedical Research in Technology Utilization, to further accelerate the flow of NASA aerospace technology toward application to problems in biomedicine was undertaken this summer for the second successive year.

The Institute was a joint project of the George Washington University and NASA's Goddard Flight Center. It was undertaken to enable ten senior undergraduate engineering students selected from a number of engineering colleges throughout the eastern United States to spend ten weeks in an active technology application program. The students were able to apply their engineering background and aerospace technology toward the solution of defined biomedical problems under the direction of University faculty and Goddard scientists and engineers. The Summer Institute was funded by the Technology Utilization Office of the Office of Industry Affairs and Technology Utilization, NASA Headquarters.

During the first half of the ten-week period, the students spent two afternoons each week in a classroom lecture series designed to provide them with a broad, comprehensive view of the biomedical engineering profession and, in particular, the systems engineering approach to health care. The lectures, seminars, and demonstrations were conducted by The George Washington University Department of Clinical Engineering in Washington, D.C.

Figure 32. Concept for Application of Anti-g Suit to Hemophiliacs

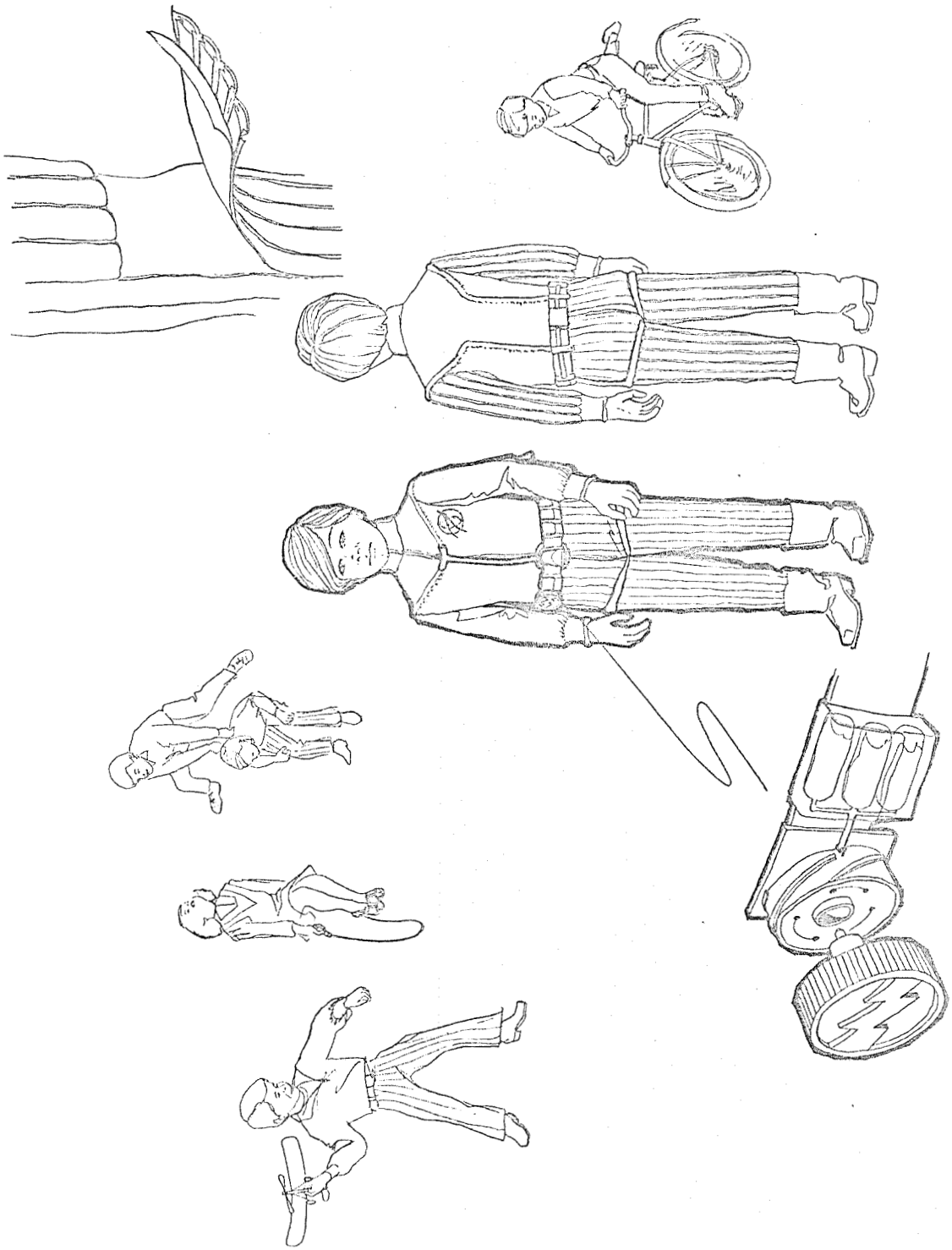


FIGURE 32: Concept for Application of Anti-g Suit to Hemophiliacs

Five well-defined research projects were developed by the Department of Clinical Engineering. These projects were focused on ideas, concepts, or existing instrumentation which needed further design and engineering improvement, so that significant progress in terms of working prototypes could be accomplished by the students during the ten-week program. These projects were:

- Electrocardiographic Electrodes for Rapid Application

  To develop an electrode suitable for a 12-lead electrocardiogram system that can be applied rapidly and provide good short-term (less than five minutes) performance.

- Heart Sound Microphone Miniaturization and Improvement

  To improve the design of microphones for detection of heart sounds, within the constraints of low cost, appropriate size, and low signal-to-noise ratio.

- Heart Sound Envelope Circuit

  To develop a new or improved circuit to simplify the phonocardiogram (heart sound) signal so that a true sound intensity signal is created for more effective use in diagnosis.

- Digital Realization of Pulmonary Screening and Motivating Device

  To develop a digital circuit equivalent of an analog computational device used to overcome the difficulties of patient motivation and or rapid separation of normals from abnormals in pulmonary screening.

- Intensive Care Alarm Indicator System

- To develop a device which can be worn by responsible hospital staff personnel and will indicate when alarms on monitoring equipment have been activated.

The students were divided into five two-man teams and each team was assigned a laboratory area, a Goddard technical advisor, and one of the defined research projects. The students worked at their own speed, but were required to record all data in a research notebook. Sophisticated testing equipment, tools, supplies, and parts were made available to the students for their research.

Much of the prototype equipment designed and fabricated by the students during the Summer Institute may be further developed by the George Washington University Department of Clinical Engineering.

More detailed information concerning the 1970 Summer Institute is included in a report issued by the Technology Utilization Office of the Goddard

Space Flight Center (GSFC). A Summer Institute will again be held at GSFC, during the summer of 1971, in conjunction with George Washington University.

OTHER TEAM EFFORTS

To solve a problem often entails much more than designing a piece of equipment or providing the details of similar problem solutions. The optimum solution to many problems require that the teams establish contact with specialists outside NASA. The research of outside specialists often help to lead to the solution of problems. Some of these contributions were described in other sections of this report.

A surgeon who needed material to implant in infants for proper drainage of cerebrospinal fluid requested assistance from a BATeam. The Team was not able to locate applicable NASA technology but it knew of Project Thrombus at the Cornell Aeronautical Laboratories. The project was concerned with materials for implantation, treated in a way so that blood clots would not form. The Team put the surgeon in touch with the researcher, and close cooperation should result in the design and test of a shunt in a relatively short time.

Nonaerospace technology which is medically related was identified by a Team as applicable to a kidney perfusion pump. A small, lightweight pump of high reliability was used to circulate vital fluids through a kidney while it was being transported from the donor to a recipient. A miniature pulsatile pump developed by the Army Research and Development Command was identified. The Team is arranging a loan of the Army pump to the researcher for further evaluation.

The Teams' broad experience and contacts frequently help in providing information to researchers. Time and effort is conserved, and the time required for medical development is reduced.

In the application of aerospace technology, the Teams have been working with the Social and Rehabilitation Service (SRS) of the Department of Health, Education, and Welfare. The Rehabilitation Research Branch of SRS is concerned with improving techniques to benefit the physically or mentally handicapped. Areas of the program to which the BATeams are contributing are:

Portable, lightweight, powered wheelchairs
Pressure-Sensitive devices for wheelchair control
Electromyographic muscle trainers
Lightweight, high-strength designs for artificial limbs
Special resins for cushioning materials
Strain gages for evaluating and fitting prostheses
An implantable valve to restore control of urinary function

In May 1971, a symposium entitled The Application of Clean Room Technology to Surgery Suites was held at the J.F. Kennedy Space Center. The meeting was attended by surgeons (orthopedic, cardiothoracic, and general), engineers, administrators, operating room nurses, company representatives and representatives of the medical journals. The objectives of the symposium were to critically evaluate present applications of clean room technology in surgery, place clean room technology in the proper perspective in the total surgery picture,

and to formulate positive action whereby the TU program can utilize NASA technology to assist the application of clean room technology to medicine. The symposium was punctual and to the point. Those attending responded with many relevant problems. The proceedings are now being prepared.

The Veterans Administration is conducting a large-scale program in the Antarctic to investigate various psycho-physiological phenomena as manifested under extreme environmental conditions. One important phase of this research involves the recording and analysis of sleep data to help advance existing knowledge concerning the process of adaptation and disadaptation to extreme environmental conditions. Most attempts to study sleep and sleep patterns have relied primarily on trained specialists for proper interpretation of EEG recordings. Working with the Southwest Research Institute Biomedical Application Team, the Veterans Administration was informed that NASA has developed an electronic sleep analyzer system capable of automatically monitoring the stages of sleep in a human subject. Its use precludes the need for a trained individual to interpret thousands of feet of EEG recordings. The NASA instrument uses selected aspects of the total available EEG signal to continually assess the subject's state of consciousness, then to make a decision concerning the level of sleep, thus eliminating the need for time-consuming expert interpretation of hundreds of hours of EEG tracings.

NASA reports describing instrumentation technology, originally developed to monitor physiological processes of astronauts in space flight, are being used in a feasibility study of remote patients diagnosis and care for rural areas. Investigators at the University of Minnesota have undertaken a feasibility study to determine available technology capable of providing rural citizens the benefits of a regional medical program without requiring them to travel to a central clinic. These investigators are examining the applicability of computer technology, closed circuit television, remote physiological monitoring systems and other similar technology. Reports of 19 major technological advances in physiological monitoring developed for NASA's space effort were located by the Midwest Research Institute Biomedical Application Team in a NASA data bank search. These developments are relevant to this problem. If these developments and other technology located by the Minnesota investigators show remote patient diagnosis and care approach to be feasible, their program will enter the demonstration phase. In mid-1971, the Washington Post reported that an experimental project had begun in which a rural doctor was provided with telephone line linkages to a computerized facility. Laboratory analyses and patient history data are among the data being provided.

ACCOMPLISHMENTS OF THE PUBLIC SECTOR APPLICATION TEAMS

APPLICATION ACTIVITY

The difficult process of bringing new technologies into the public sector environment requires extensive review and consideration of the complexities of public sector problems. The TATeams must interface with a wide range of public organizations to fully identify these problems. They must also identify and evaluate mechanisms, both public and private, which may be capable of facilitating the actual application of the technology. These tasks, as well as those of technology identification and evaluation, make up the complex functions required of this relatively recent program innovation.

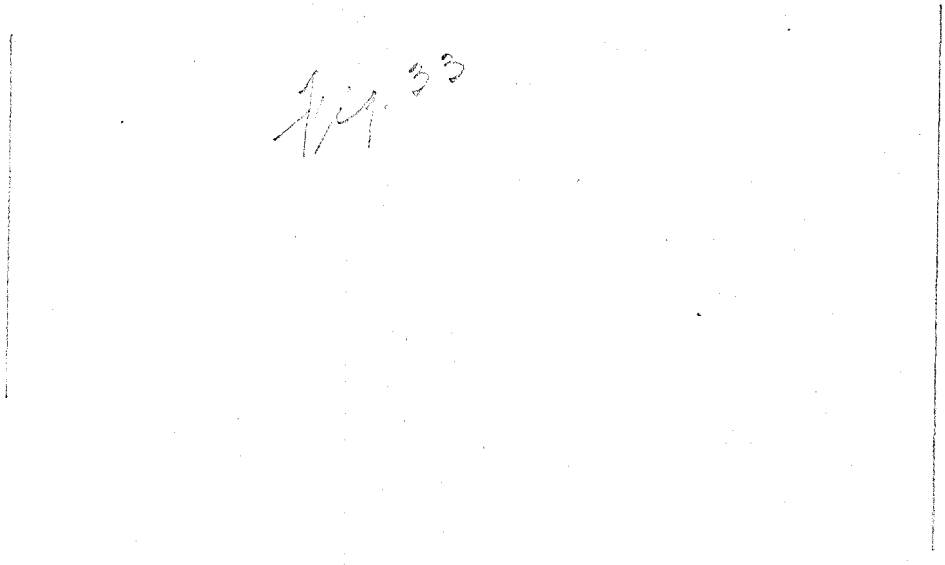
During the period covered by this report, the Technology Application Teams have expanded their scope of problem identification efforts, their knowledge of public sector needs, and their understanding of barriers to technology application. They have also brought a wide range of problems to the stages of adaptive engineering and performance test evaluation. The solutions to other problems have progressed to the stage where the Problem Originator has accepted the concept, and a physical model is required for test, evaluation, or adaptation.

The application process has been aided by four factors. First, the teams have exhibited a high degree of motivation and creative effort in their modes of operation. Second, much knowledge of application methodology was gained from the BATeam experience. Third, the NASA field center Technology Utilization Offices and scientific personnel have given the program outstanding cooperation and support in the identification of applicable technology and expertise. Finally, NASA's recent efforts to facilitate applications engineering have greatly assisted team effort, since it is vital to illustrate technological feasibility to potential public sector adapters of aerospace technology.

The Technology Application Program is necessarily accompanied by delays in time due to a variety of circumstances. For example, requirements for adaptive engineering, performance trials, procurement efforts, descriptive documentation for concerned parties, and other delaying factors. However, such applications of available advanced technology have resulted in substantial savings of time, effort, and money when compared with the time and resources which would be required to initiate new research and development to solve a particular problem.

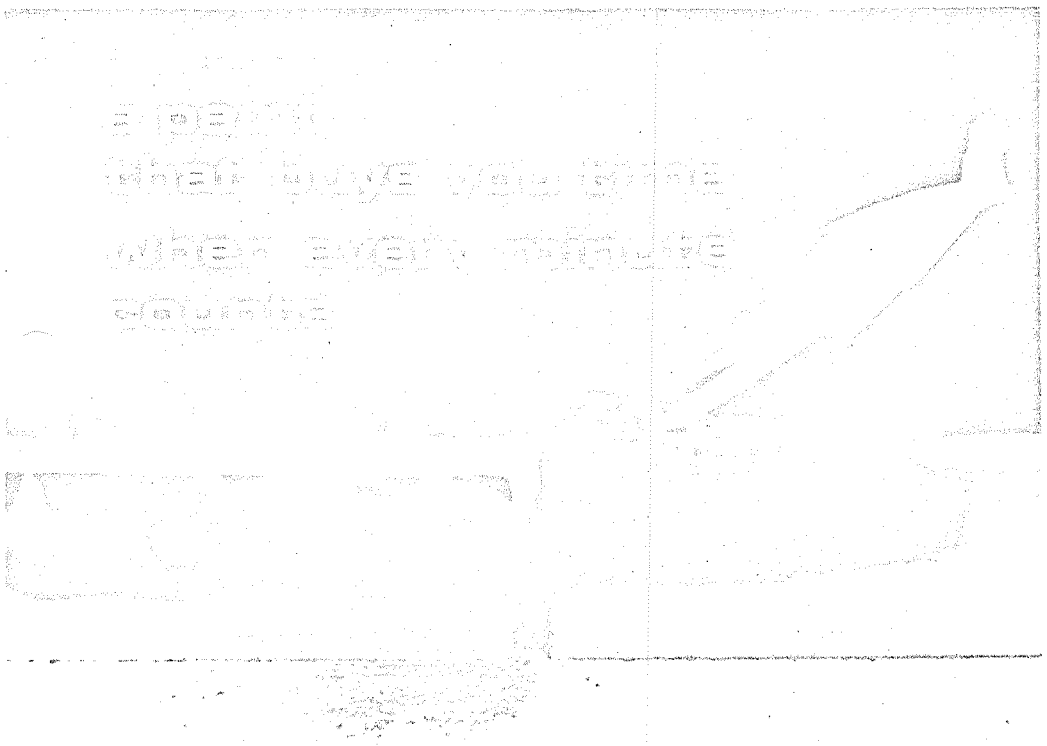
The following paragraphs describe a wide range of problem-solution matches to which aerospace technology is being applied.

Fire Retardant Coatings--Intumescent Paints. Intumescent paints, which swell when heated to form an insulating carbon char, have been commercially available for some time. However, many of these commercial paints tend to be deactivated in high-humidity conditions; they do not have good color stability; they have poor mechanical properties; and they accept pigmentation poorly. NASA's Ames Research Center has developed a new class of intumescent paints which eliminate these undesirable properties (Figures 33 and 34).



NASA-developed fire retardant coating, recently advertised in technical magazines, exhibits improved weathering properties.

Figure 33. Intumescent Paints

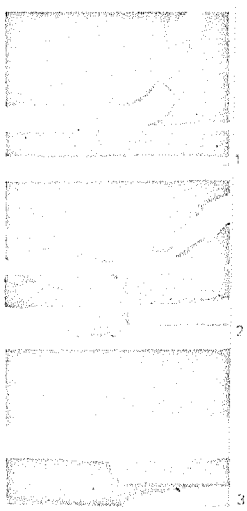


From the people who made the Apollo Heat Shield now comes an exotic new paint that can prevent fire damage to metal, wood, plastic, and other materials.

Called FLAMESHIELD, it expands 150 times in thickness when exposed to fire. The expanded coating keeps damaging heat and flames away from the base material. FLAMESHIELD doesn't put the fire out, but it does buy time – time to prevent costly damage, or maybe save a life.

Extra minutes of protection can save: valuable manufacturing equipment, files, storerooms, hazardous areas, and critical parts of trains, planes, boats – broad protection for both home and industry.

FLAMESHIELD – an all-weather paint – can be applied *inside or outside* with brush or standard spray equipment. It dries quickly, resists humidity and other environmental conditions. And, it's available in quantities from quarts to 55-gallon drums.



Obtain more information on this new line of protective paints by phoning or writing: FLAMESHIELD, Avco Systems Division, Lowell Industrial Park, Lowell, Massachusetts 01851, Tel. (617) 452-8961.

Test shows dramatic results from FLAMESHIELD paint protection.

One wood block is painted; another unpainted (photo No. 1).

Torch triggers action as paint forms thick, tough layer of insulating foam on painted block (photo No. 2).

Minutes later, painted wood shows virtually no effect after foam is scraped away; unpainted wood is damaged and would show even further deterioration if fire continued (photo No. 3).

AVCO SYSTEMS DIVISION
LOWELL INDUSTRIAL PARK LOWELL, MASSACHUSETTS 01851

FIGURE 33: Intumescent Paints

Test of fire retardant intumescent paints, showing coated and uncoated structures. Photograph 4 shows the heavy layer of char which acted as an insulation.

Figure 34. Intumescent Paints

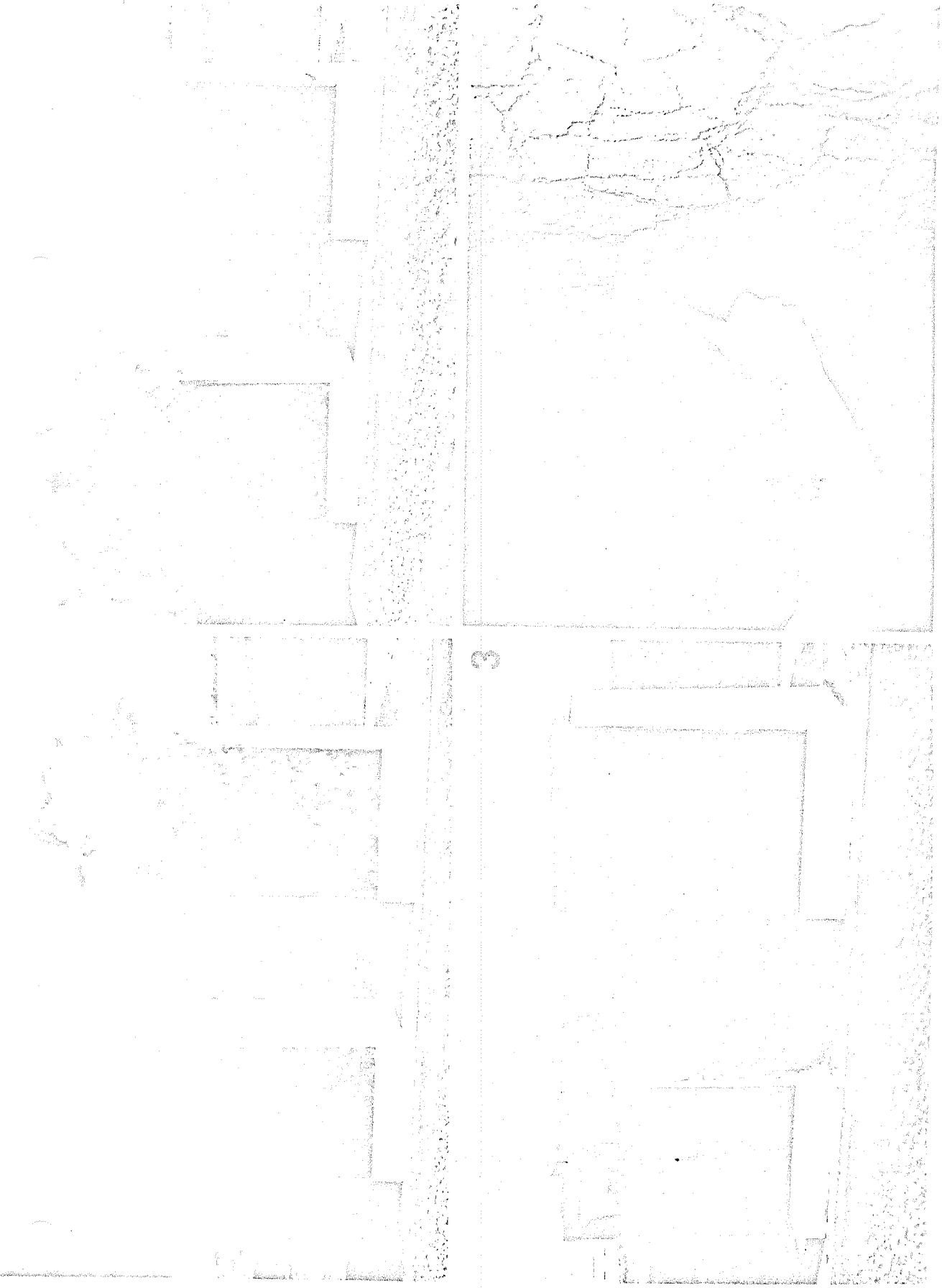


FIGURE 34: Intumescent Paints

Significant advantages of the NASA paints over commercially available coatings are their hydrolytic stability, their superior optical and mechanical properties, and the greater heat stability of their char. Disadvantages of NASA's coatings include a toxicity problem resulting from SO_2 given off from the film upon expanding, and ultraviolet degradation of the binder upon exterior exposure.

The intumescent agents developed by NASA are monomers based on p-nitroanaline and sulfuric acid, which undergo a complex series of condensation reactions when heated to temperatures above 350°F. Gaseous products are produced (H_2O, SO_2, N_2) simultaneously with a black, char-like, heterocyclic oxidation-resistant polymer. The polymer is blown into a low density surface foam by the escaping gases. This char is stable to temperatures of 1000°F and its low density (0.1 to 0.3 lb ft^3) and closed cell structure result in very low thermal conductivities for excellent heat protection.

The Abt TATeam identified an application for these new NASA paints as suggested by the National Association of Home Builders. Fibre Reinforced Plastic (FRP) shower stalls and tubs have been a source of fire in buildings under construction. Plumbers, accustomed to working with metal fixtures have on occasion set fire to the FRP with pipe soldering torches. The manufacturers of the FRP fixtures needed to protect the areas that the torches might burn, so the International Association of Plumbing and Mechanical Officials, and the National Association of Home Builders (NAHB) Research Foundation developed a test procedure for these fixtures. The test involves placing a 1-inch flame from a propane torch on the FRP for 30 seconds and timing the duration of the resulting burn, waiting 2 minutes and repeating the test at the same spot. In no instance may the FRP continue burning more than 30 seconds after removing the flame.

The AVCO Corporation is producing intumescent paint under a NASA license. When samples of FRP fixtures were coated with the AVCO intumescent paint and tested at the NAHB Research Foundation Laboratories, durations were under 10 seconds with indications that less than 5 mil thicknesses of the paint would provide adequate protection. AVCO is currently surveying other potential markets and applications for the intumescent paint.

Intumescent Mastics. Mastics are high viscosity, pasty materials used as protective coating or cements. Because steel loses its structural strength early in a fire (steel strength at 950°F is 40% of strength at 70°F) some building codes require compensating protection. Michigan, for example, requires 1-hour protection for structural steel in school buildings, and New Jersey requires 30 minutes. Mastics are generally applied with spray equipment to a one-half inch thickness. Concrete is a commonly used mastic material.

The potential solution to this fire-protection problem was located through contact between the TATeam and Ames on the general subject of non-mastic intumescent coatings. NASA, as a result of its interest in heat ablation, has developed a new, highly stable class of intumescent materials which can be formulated as mastics by the addition of short fibres of glass. The Ames Mastic 313 was developed by the Chemical Projects Research Office. Currently, a sample of the mastic has been prepared by Ames, and tests are being conducted by AVCO to compare the NASA mastic with two commercially available

materials. When the tests are completed, the Urban Development Corporation will evaluate the utility of this material for use in their program for building a large number of housing units in New York State.

Fire Retardant Foams. The Abt TATeam has established that there is a great need for fire-retardant foams in the construction industry. NASA's Ames Research Center has developed a class of fire retardant foams based on isocyanurate (ICU) chemistry principally for use in military aircraft. These foams may find use in thermal insulation and fire resistant paneling for buildings. Isocyanurates, formed by the trimerization of isocyanates, are flame retardant because their molecular bonds have been modified to become inherently more temperature stable. The fire performance of ICU foam has been characterized in a NASA fire simulation facility designed to simulate the radiative and convective heat fluxes associated with large fires. The time taken for a thermocouple located 2 inches below the heated specimen surface to reach 200°F is a measure of the fire performance of commercial foams with which the ICU foam was compared. ICU is available from the AVCO Corporation in containers up to a 55 gallon drum size.

Samples of the ICU foam have been given to Housing and Urban Development and arrangements have been made to have the Ball Corporation, an Operation Breakthrough winner, evaluate the foam. The foam will be evaluated both for difficulty of fabrication and fire retardancy. Fire retardancy tests required by the National Bureau of Standards and the American Society for Testing Materiels (ASTM) are not compatible with the NASA test data. If the evaluation is positive, Ball Corporation will test the foam in a practical configuration.

The foam has also been proposed to the New York Urban Development Corporation (UDC) for areas of great fire danger (i.e., kitchen range, furnace, etc.). The UDC is interested because of a fire that occurred in a modular housing unit in upstate New York. The module used polyurethane extensively, and the foam was a major problem in the fire. UDC is also interested in ICU foam as a possible panel core material for lightweight fireproof partitions.

Subsurface Soil Examination for Construction Industries. Parts of Rock Springs, Wyoming, are sinking into the ground. Gas lines have cracked, houses are splitting at the seams, and community morale is low. Rock Springs was built over abandoned coal mines, and now the mines are caving in. Adequate preconstruction soil testing would have prevented this financial disaster.

Building designers and constructors, particularly those involved with small buildings such as individual homes, are generally not able to conduct an exhaustive soil exploration on each building site. With only the visible area of the prepared foundation-bearing surface available for examination, foundations may accidentally be located over sink holes which will cause collapse of the foundation or structure at some point during the construction or occupancy. An inexpensive, reliable method for detecting and pinpointing the location of such holes would allow them to be filled, or force relocation of the foundation site.

In urban renewal projects, the debris buried by past users of the land can cause major delays as well as increase the expense of new construction.

The concrete foundations from a removed mill building, for example, may require major demolition and removal efforts if they are located where a foundation for a new building is to be laid. If such subsurface debris could be found prior to final site planning for new facilities, interference could be minimized. Reliable techniques for locating and predicting the composition of such buried debris could substantially improve the effectiveness of urban renewal programs.

A potential solution to this problem, found by the Abt TATeam, is a novel instrument conceived for use on the moon or the planets but readily adaptable to terrestrial uses. It can determine layering and structure as deep as 100 feet below the earth's surface; it determines the physical properties of the subsurface by determination of variation in the dielectric constant of the surface and subsurface layers, as a function of depth; it can identify different types of material by passive-emissivity measurement in the ultra-high-frequency (UHF) region of the electromagnetic spectrum; and can locate subsurface deposits of moisture. It can also accurately locate deep faults and hazards, and thus isolate areas having poor bearing strength. The UHF infrared radiometer yields subsurface temperature profiles which provide emissivity profiles down to 100 feet. Regions of anomalous emissivity and thermal properties can be easily isolated. Subsurface materials and geologic deposits are thus three-dimensionally identified.

NASA funding provided for concept development only. Martin Marietta has elected to continue the project at a lower level of effort. They have developed a prototype which they are currently field-testing over snow, ice, and water. They will soon test it over soil to further prove the concept. Abt will then help to raise additional funds for development.

Ultrasonic Torque Wrench. Rivets are no longer used in building construction. Unless a bolt is tightened into its elastic region, normal vibrational forces can loosen the connection and cause structural failure. Excessive torquing stretches the bolt into its inelastic region and rupture may result. Accurate measurement of the clamping force of a bolt is complicated by the frictional forces present. The force required to overcome friction is highly variable and exceeds the force required for axial extension of the bolt. As a result, architects often overdesign structures, resulting in added structural costs in both material and labor.

The Abt Technology Application Team approached several NASA Technology Utilization Offices with the problem. The Marshall Space Flight Center responded by describing an ultrasonic wrench, designed by a NASA contractor and used to insure leaktight connections when assembling fluid distribution systems.

To use it, the operator first tightens the nut to the specified torque as observed on the dial indicator. He then depresses the thumb switch, exciting the transducer to the preset power level. The ultrasonic torque wrench system induces a flexural vibration mode in the nut. During the fixed 3-second pulse application, the operator maintains the desired torque as the ultrasonic energy reduces friction and permits additional tightening of the nut to occur.

The system consists of a frequency converter, a junction box, and a wrench assembly. The frequency converter (a solid state circuit in a standard

switch box) converts line power to 28kHz, times to provide 3-second output pulses. The junction box contains an impedance matching network, a transformer, an inductance coil, an overvoltage spark gap, a cooling-air regulator, and an air pressure gage. The wrench assembly incorporates a lead zirconate titanite transducer, which delivers from 70% to 85% of the high-frequency electrical power into an acoustic load, and is provided with a standard dial indicator, calibrated in inch-pounds of torque. Open-end wrench leads for each fitting size are mechanically interchangeable by means of a precision acoustical junction.

A prototype ultrasonic wrench was delivered to an interested commercial company by the Marshall Space Flight Center in January 1971. In conjunction with the TATeam, the company planned a test program for the wrench. Initial test results indicate that the wrench is not cost-effective in improving the consistency of actual axial bolt tension for a given applied torque. Possibly a substantial increase in vibrational power and a different mode of vibration would yield more significant results, but this will require more exploratory work.

Extendable-Retractable Probe. A search for a device to actuate automatic garage doors with increased reliability and at reduced cost has located a potential solution which has been accepted by the Problem Originator. Uses include homes, fire stations, freight depots, and other municipal buildings. Several NASA-developed extendable/retractable booms were located by the Abt TATeam through literature searches, but it appears that a device developed at Goddard Space Center is the one that will be used. The probe is designed to retract into a very small package, or to extend to a length of 10 to 20 feet. A mechanical cable is connected from the end of the probe to the garage door, and an electrical cable is connected to a remote sensing device. When the probe is actuated by the remote sensing device, it extends and the garage door opens. This device is currently under evaluation by the Problem Originator as a possible commercial product.

A Low-Cost, Reliable, Fire Warning System for Use in Residential Dwellings. Early smoke detection is one of the top priority technological requirements of HUD's Operation Breakthrough Program. The requirement was underscored in HUD's Guide Criteria for Operation Breakthrough, which requires that smoke detection and alarm systems be installed in multilevel dwellings under the program's sponsorship.

Alternate technological approaches for a solution to this problem were developed by the Abt TATeam in conjunction with members of the Massachusetts Institute of Technology (MIT) Urban System Laboratory. Approaches included infrared, ultrasonic, and ultraviolet detection methods. The team identified a new polymeric material, polyphenlyacetylene, which has electrical properties that change as it absorbs gases or particulates. The polymer acts as an effective contaminant detection device when used as a coating on a field effect transistor (FET). The FET can detect the polymer's changing electrical properties and actuate an alarm device. McDonnell-Douglas Corporation, the inventors of the detection device, developed it for use on the NASA Voyager mission. Applications engineering to refurbish the device is being considered so that preliminary tests can be made.

This smoke detector is at least as good as current available devices in distinguishing between cigarette smoke and incipient stages of a fire. The installed cost has not yet been estimated, but is expected to be significantly lower than for the lowest price unit currently on the market. The impact of a low-cost device could be significant. Not only would more homeowners be able to afford a system, but better protection would be available for everyone.

Indented Writing Detection. One of the most important pieces of evidence confiscated during a gambling raid may be a writing pad which was used to record betting information. Even if the page bearing the writing is destroyed, the pages underneath often carry an indented impression of the writing. A device which will recover this indented writing would facilitate the solution of criminal cases.

Retrieval of indented writing depends on the backing beneath the second sheet, the quality of the papers, the shape of the writing instrument, and the writer's pressure. If the writing is clear and visible, techniques such as side-lighted shadow-casting, thermosetting plastics, or various photographic approaches may reproduce it. If it is indistinct or superimposed, most approaches are quite fruitless. An interesting fact--and one that destroys an old amateur detective technique--is that pencil "shading" is virtually never used in actual practice since it will destroy the information rather than aid in its recovery.

A fiber optics profilometer (Figure 35), developed for NASA's Marshall Space Flight Center by MetroPhysics Inc., showed promise of meeting the requirements. The profilometer was originally used to detect flaws on the surface for rocket tubes. The Illinois Institute of Technology Research Institute (IITRI) TATeam recommended that the technique be considered for detection of indented writing.

The probe is a simple reading device and consists of a bifurcated fiber bundle encased in a housing of black lucite (Figure 36). After being encased, the end plane of the bifurcated bundle is ground flat and polished. The bundle itself is made of layers of fiber ribbons. Every other layer is brought up to a viewing plane (Figure 37) where spacers are placed between the layers. Thus a bundle of viewing fibers is obtained which are oriented in such a way that undistorted imaging is maintained. The remaining fibers that end at the sample plane are assembled into a bundle without regard for orientation and serve to illuminate the sample surface (transmitting fibers).

When a sheet of paper that does not have indented writing is placed on the sample plane (Figure 38) no light emanating from the transmitting fibers can reach the viewing fibers. But with indentations in the surface of the sheet, light from transmitting fibers at an indentation is reflected into the neighboring viewing fibers. Images of indentations are thus obtained in the viewing plane as bright spots against a dark background. They have proved to be good facsimiles of the original writing.

Although the agency which identified this problem was the Chicago Police Department, the Law Enforcement Assistance Administration (LEAA) of the Department of Justice showed an interest in the problem and funded a prototype for a

Fig 35

Device permits the detection and recovery of indented writing by law enforcement agencies.

Figure 35. Fiber Optics Profilometer

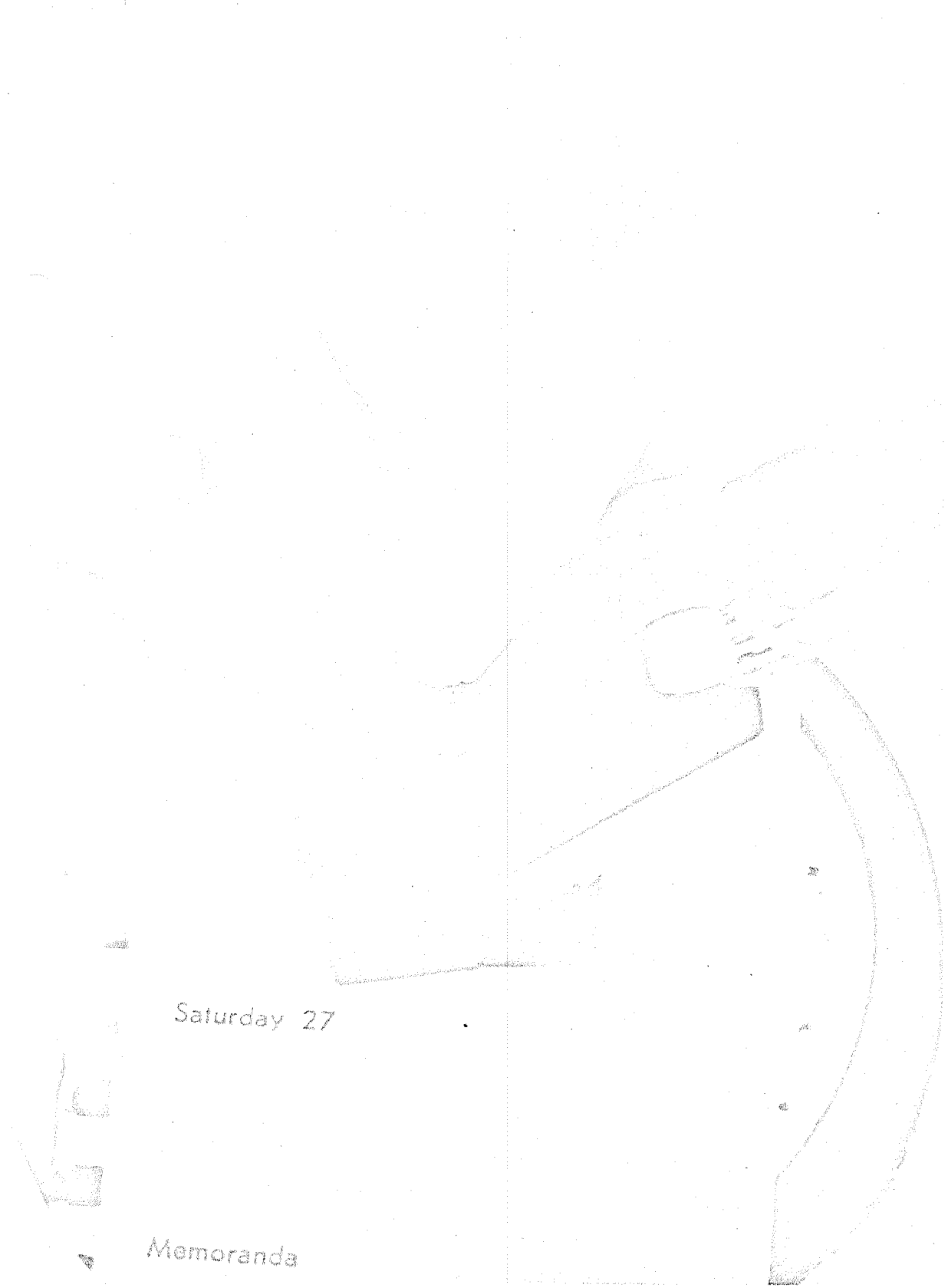


FIGURE 35: Fiber Optics Profilometer

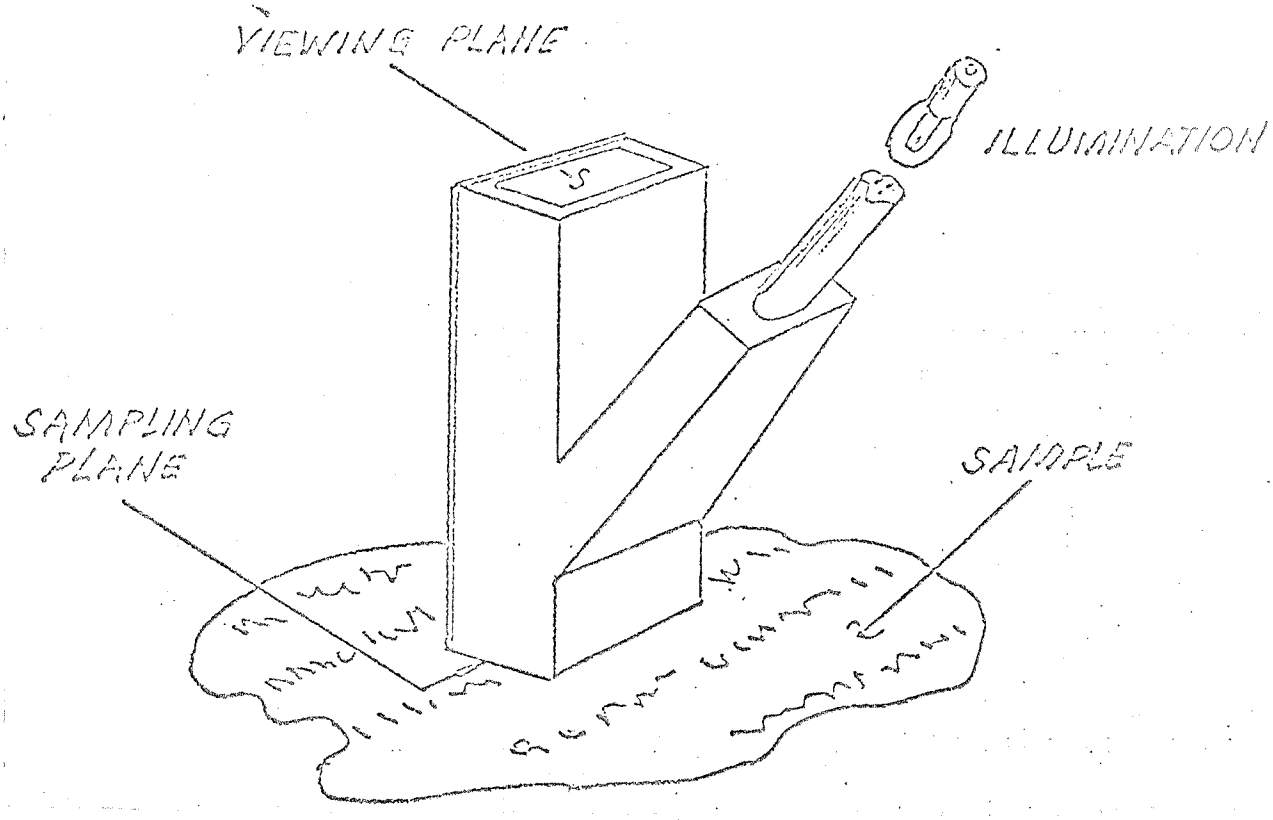


Figure 36. Fiber Optics Housing

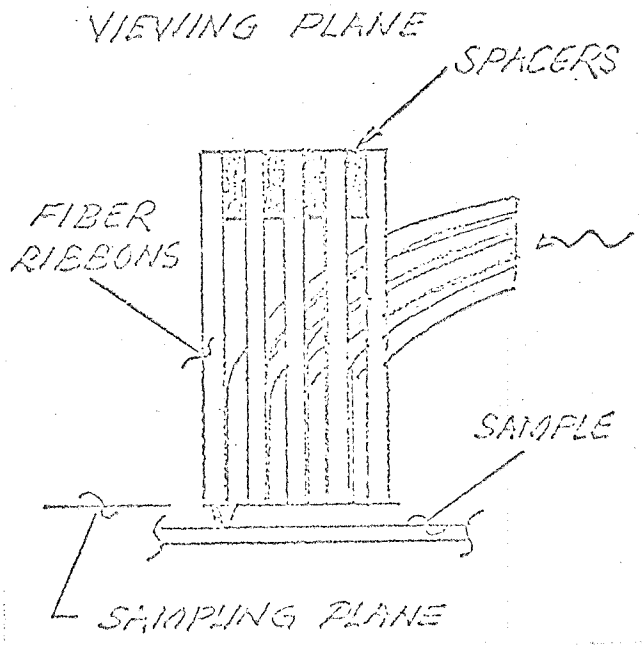


Figure 37. Cross-section of Housing

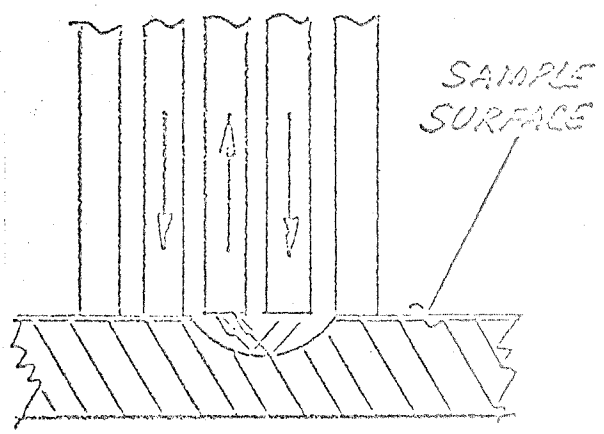


Figure 38. Incident and Reflected Light Paths at Sample Surface

feasibility demonstration. Funds for the effort were not available from the Chicago Police Department.

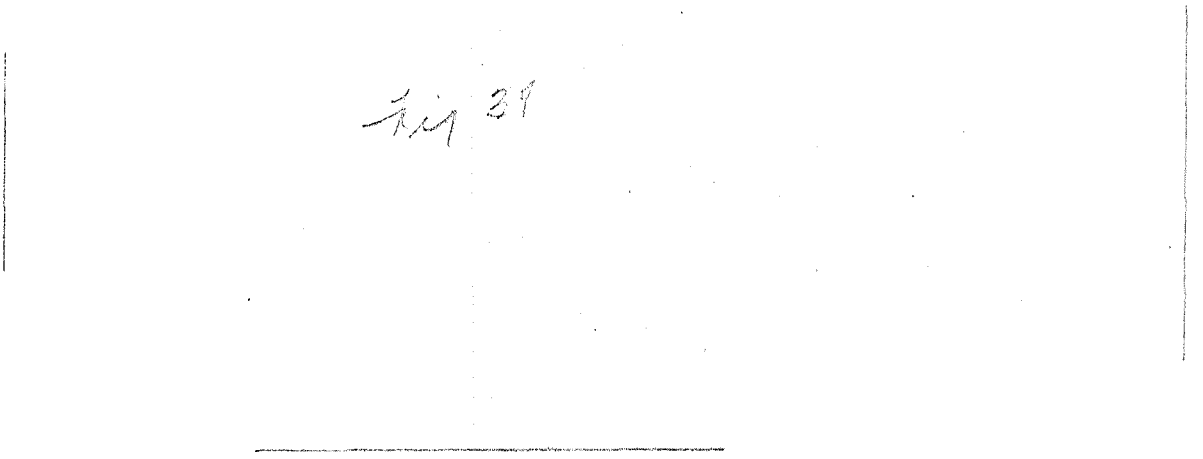
MetroPhysics made the necessary modifications to the device and conducted a test program. Tests showed that further modifications were required. Specifically, because of translucency of the test paper, there was light scattering within the paper that resulted in background noise. Efforts to rectify this were successful to a degree. The TATeam then demonstrated the device to Chicago Police Department (CPD) officials who were impressed with the potential of the device. The CPD retained the device for further evaluation under operational conditions. The device was then demonstrated to the LEAA and received a favorable reception from their technical personnel. MetroPhysics has prepared a cost-sharing proposal for an air-improved prototype device. A meeting was held with MetroPhysics and the CPD to finalize the design. The CPD has agreed to test, evaluate, and report on the prototype.

Several significant features of the technology application process were demonstrated by this effort. Foremost is that many Problem Originators lack funds for development of potential solutions and adaptation to a program. Equally important, however, is that federal mission agencies such as LEAA are seriously interested in furthering innovative progress.

Measuring Reflection Spectra of Very Small Samples. The California Criminal Identification and Investigation Bureau presented the Southwest Research Institute (SRI) TATeam with a problem common to all criminalistic laboratories: identification of an automobile from a small paint scraping left in a hit-and-run accident. It has been the practice to make a visual comparison of the scraping with sets of manufacturers' standard paints by means of a binocular microscope. But comparison is frequently difficult and sometimes impossible. A more objective instrumental comparison method would be desirable because it could provide evidence in quantifiable and reproducible form and facilitate the identification of the car.

A solution was suggested by a NASA scientist at Goddard Space Flight Center, tested experimentally by him, and evaluated by forensic scientists. The solution, as shown in Figure 39, is to mount the paint sample in the integrating sphere which serves as the reflectance attachment of a visible ultraviolet spectrophotometer. Normally, a very small sample will give no measurable absorption in this position. However, the integrating sphere has as its interior surface a diffuse reflector. The sphere increases the number of times the ray hits the sample by mounting a convex lens in the integrating sphere so that its focus coincides with the sample. This has the effect of enlarging the apparent sample surface approximately to that of the lens surface. Any ray that hits the outer surface of the lens is focused onto the sample and is reflected from it. Thus, the absorption signal is greatly increased and can be recorded in the usual manner. Any of several commercially available spectrophotometers may be used for this work. The proposed system is inexpensive, easy to calibrate, and does not have any adverse effect on the spectrophotometer to which it is attached.

One set of samples analyzed by Goddard Space Flight Center was from an actual California case. While the Sheriff's office thought that two paints were different they had no objective way to determine the difference in



Ultraviolet spectrophotometer, with modified integrating sphere to serve as reflectance attachment, used for criminalistic evaluation of paint chips.

Figure 39. Paint Chip Analysis System

colors. The modified spectrophotometer showed that the two paint samples were different red paints and helped to exonerate an individual.

A description of the spectrophotometer system will soon be published in a criminalistic journal. This will help to provide the crime laboratories with a justification for the purchase of necessary equipment, and for the incorporation of this technology into their daily operation procedures.

Time and money can be saved by using this technique. Of the 50,000 annual fatalities, if only 0.5 percent, or 250 cases were decided by unquestionable physical evidence and never brought to trial, the savings may be as much as $1,000,000 in laboratory, investigative, legal, and court costs. In addition, there are more than 1,000,000 injury accidents without fatalities. Many of these also require criminal investigations in which similar savings per case are possible.

Hidden Object Metal Detector. An SRI TATeam problem closely tied to current events is concerned with metal detectors. An efficient system for detecting and locating metal objects, particularly guns, is required for a multitude of law enforcement purposes. An important need has been established for the detection of metallic objects prior to passenger boarding of airplanes. Recent events show that a detection system may be necessary for use on persons entering special trial courtrooms, or for persons entering public buildings.

A metal detection system developed by the Ames Research Center can search people inconspicuously when they enter areas where metallic objects are prohibited. The detection is accomplished by a phase-sensitive (polarity) detector, sensitive to both ferrous and nonferrous metallic objects. The basic detector consists of two large coils placed on either side of the item, or

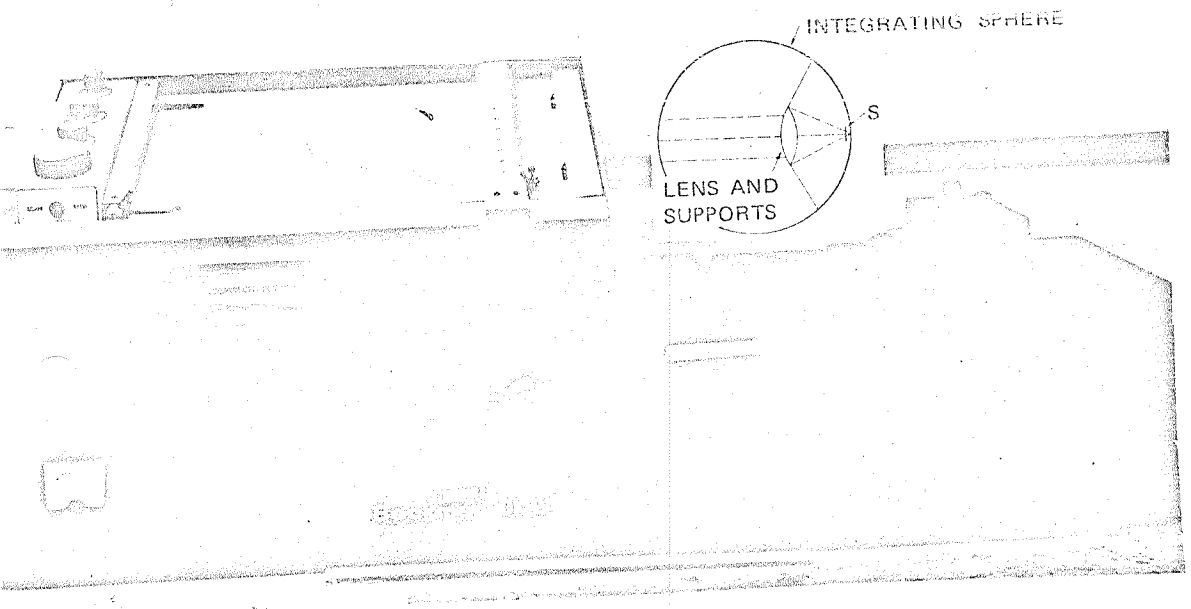


FIGURE 39: Paint Chip Analysis System

person, where metallic objects are to be detected. The signal voltage resulting from disturbance of an electromagnetic field within the volume of the sensitive area is compared with a reference voltage for polarity information and thus identifies the material. Output amplitude and polarity indicate the approximate size and type of material. The system is insensitive to metallic objects below a specific size, and its output is independent of the speed with which an object moves past the detector. The output may be signaled by lights, by an audible alarm, or by a chart recorder.

The system has been successfully demonstrated to representatives of San Mateo County, California, who are interested in its courtroom application. It has also been demonstrated to the Department of Transportation's Federal Aviation Administration which is evaluating antihyjacking measures. Ames is now awaiting funding from NASA to further develop this device. The Department of Transportation's Transportation Systems Center may also support development of the device. An estimated 6 months will be required to build a prototype for field testing.

Communications Link: Automatic Trouble Shooting. Many state and local police departments employ data communications systems to connect a central computing facility with terminals at remote field stations. Interruptions in the flow of the data are sometimes caused by telephone network failures, however, and valuable time is lost while the sources of the trouble are manually traced. The main difficulty stems from the fact that there is no quick means of demonstrating to the telephone utility that the fault lies within the telephone network. Because downtime in the data system is costly, both in terms of lost computer time and criminal apprehension, the police are often forced to lease the highest quality, and most expensive telephone lines available.

A "hardline" monitor (Figure 40), developed at NASA's Kennedy Space Center, gives a continuous check on the quality of data communication cables in the Center's automatic checkout system for testing the components of a launch vehicle. This monitor is capable of continuously sampling 16 telephone lines and warning operators when the quality of transmission has deteriorated beyond recognized tolerances or when the line has catastrophically failed.

The monitor's circuitry can be adjusted for variable acceptance levels of incoming data to conform to the requirements of the receiving equipment. These critical parameters included amplitude, rise-time, frequency response, and background noise. When the quality of the line approaches the preset limits a warning command is given from the monitor. In operation the monitor continually scans all the lines in a selected sequence. It analyzes data being transmitted over the line and interrogates those lines with no data. The interrogation involves simulating a small transponder at the other end of the line to send a generated set of pulses for evaluation.

The IITRI TATeam passed technical details of the monitor to the Maryland State Police in October 1970, and the the New York State Identification and Intelligence System (NYSIIS) in December of 1970. The latter estimated that their use of a similar monitor would produce an annual saving of $50,000 by eliminating the need for leasing the highest quality telephone lines.

A meeting was held at the Kennedy Space Center to demonstrate the device to representatives from Maryland and New York. Both state agencies agreed

fig 40

Monitor provides continuous check on data communications cables, and may be used by police departments to monitor hardline transmission quality.

Figure 40. KSC Hardline Monitor

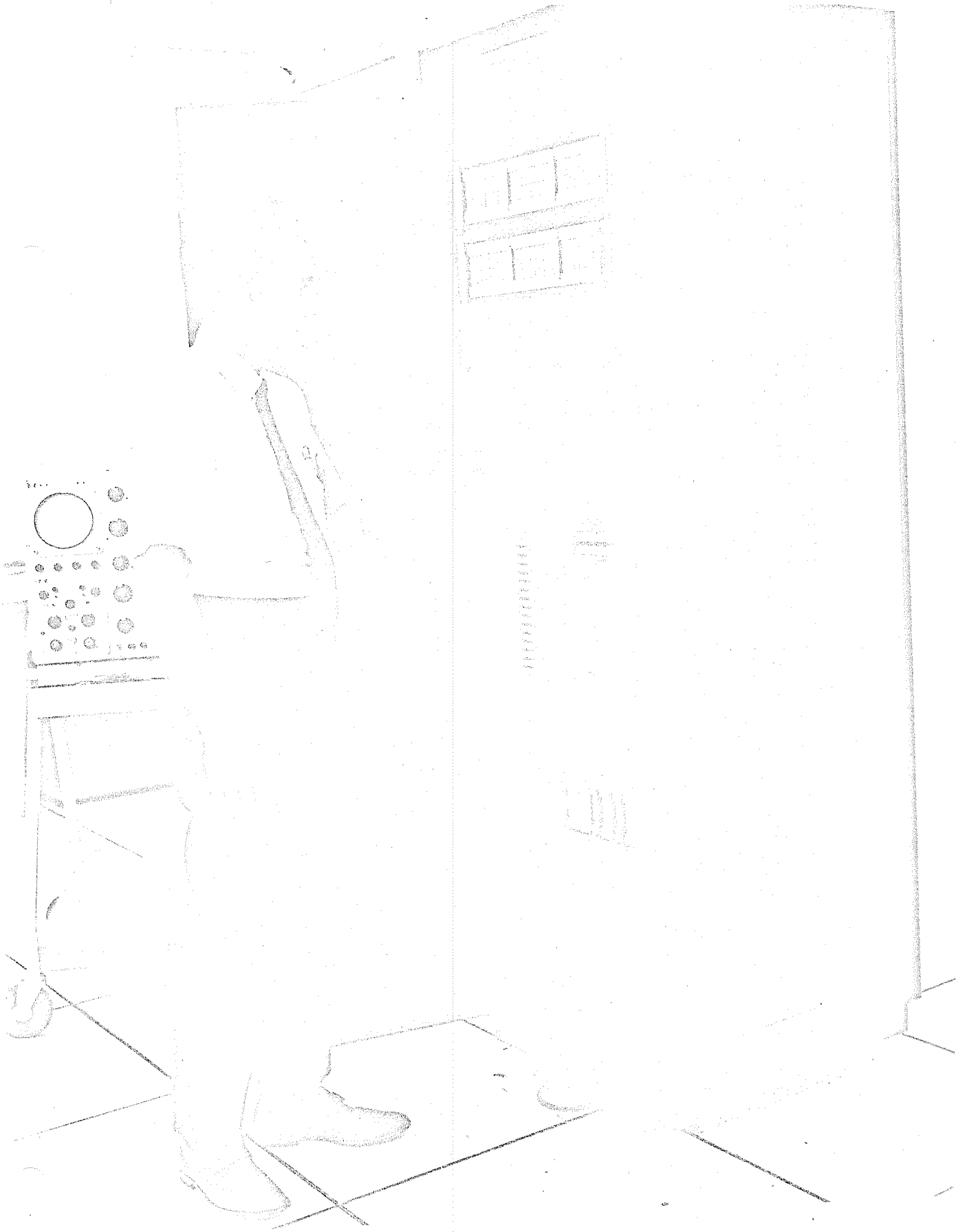


FIGURE 40: KSC Hardline Monitor

that the monitor would meet their needs. The TATeam will perform a system design study of NYSIIS requirements for the inventor. The NASA inventor will then build a prototype hardline monitor, and the NYSIIS has agreed to serve as a test site.

Fingerprint Image Enhancement. Fingerprint records generated at field stations in New York are transmitted by facsimile equipment to a central facility, the New York State Identification and Intelligence System (NYSIIS), where they are received, cataloged, and stored. About 60,000 prints are transmitted this way each year in the New York State system. An estimated 40 percent of these are not usable, due to smudges, prints that are too light, or distortion during transmission. It would be advantageous to law enforcement authorities if these poor quality prints could be restored to a readable state.

While investigating this problem, the IITRI TATeam was made aware of a computer processing method that could be applied to enhancing the details in photographs. This method, developed by the Jet Propulsion Laboratory (JPL), has been used to enhance the detail of photographs taken during space probes of the moon and other planets. It has proved applicable to other problems as well, such as the enhancement of medical X-ray photographs. It appeared reasonable that this method would be applicable to sharpening distorted facsimile-transmitted fingerprints (Figure 41).

The potential solution has been presented to and accepted by the NYSIIS as a possible solution to the problem. The JPL is currently conducting a series of tests on meaningless fingerprints made available to them by the NYSIIS. If the legibility of the fingerprints is successfully restored, efforts will be made to adapt the method to the NYSIIS system.

The benefits from solving this problem are not limited to restoring the legibility of unreadable or distorted fingerprints. Since 40 percent of the annual volume of transmitted fingerprints must be retransmitted, such a solution will eliminate almost 6,000 hours of facsimile machine and operator time.

Simple Analytical Methods for Drugs. A large part of the workload of criminalogic laboratories involves drug analyses of two types: determination of the daily identity of seized samples; and determination of drug levels in blood, urine, and other physiological specimens. The latter is more difficult since the drugs are present at very low levels. Although analytical instrumentation currently exists, simpler analytical methods are being sought.

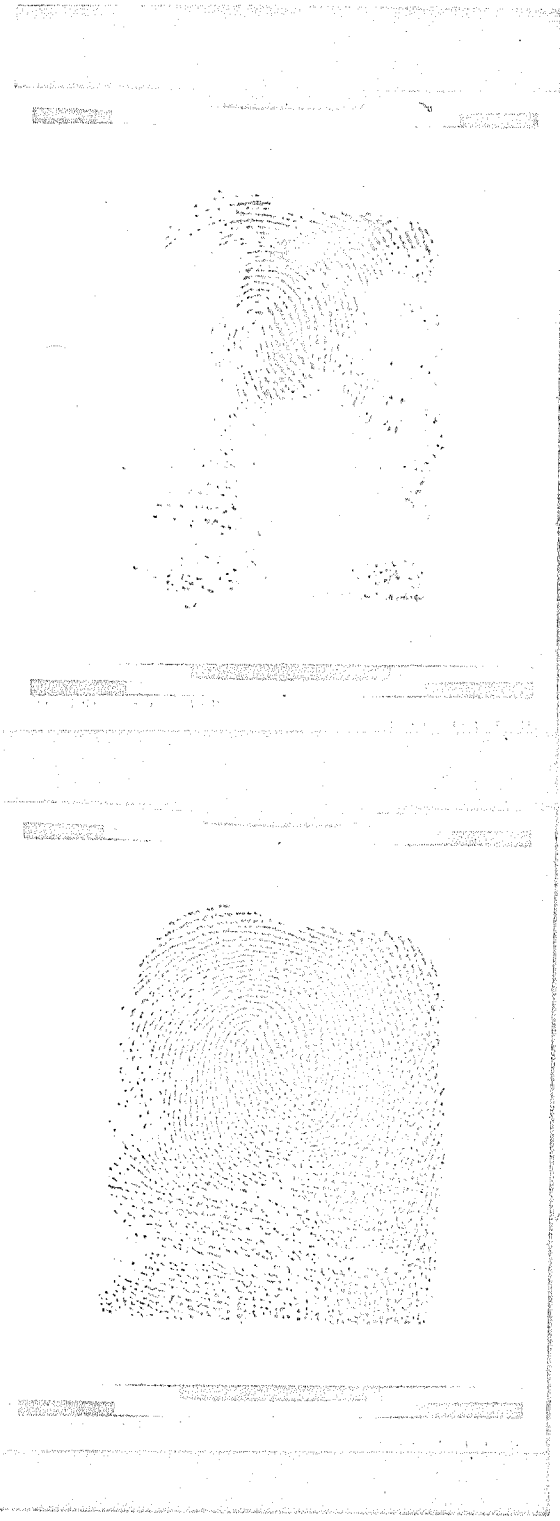
Specifically, New York City has the problem of analyzing the morphine content of urine taken from suspected heroin users. Heroin is broken down into morphine derivatives when injected into the body. Urine samples currently are collected and analyzed by a private firm which cannot return the results in less than 3 days from sampling. The suspects cannot be held for that length of time and are often released before the analytical results are received. A request was forwarded to NASA's Ames Research Center by the Southwest Research Institute (SRI) with the question: Can the morphine analysis be accelerated and still meet physical evidence requirements?

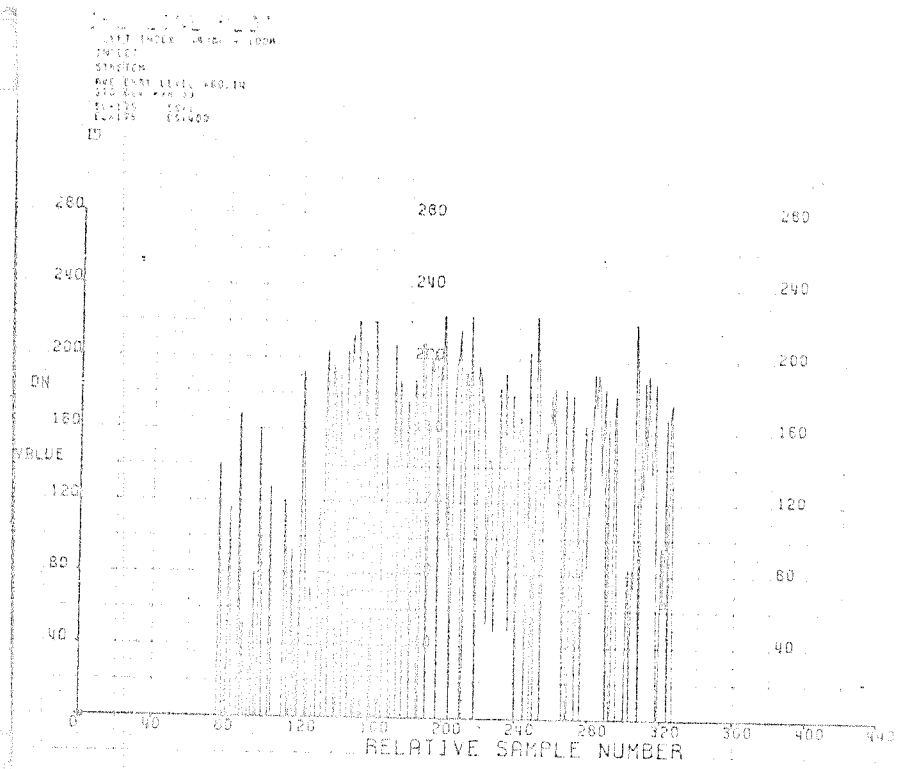
Ames now has a breadboard model of a morphine analyzer. Scientists at Ames are preparing a proposal to obtain NASA funding for an automatic device

Fig 41

Computer processing method used to enhance the detail of photographs from space which is applicable to sharpening distorted facsimile-transmitted fingerprints.

Figure 41. Fingerprint Image Enhancements





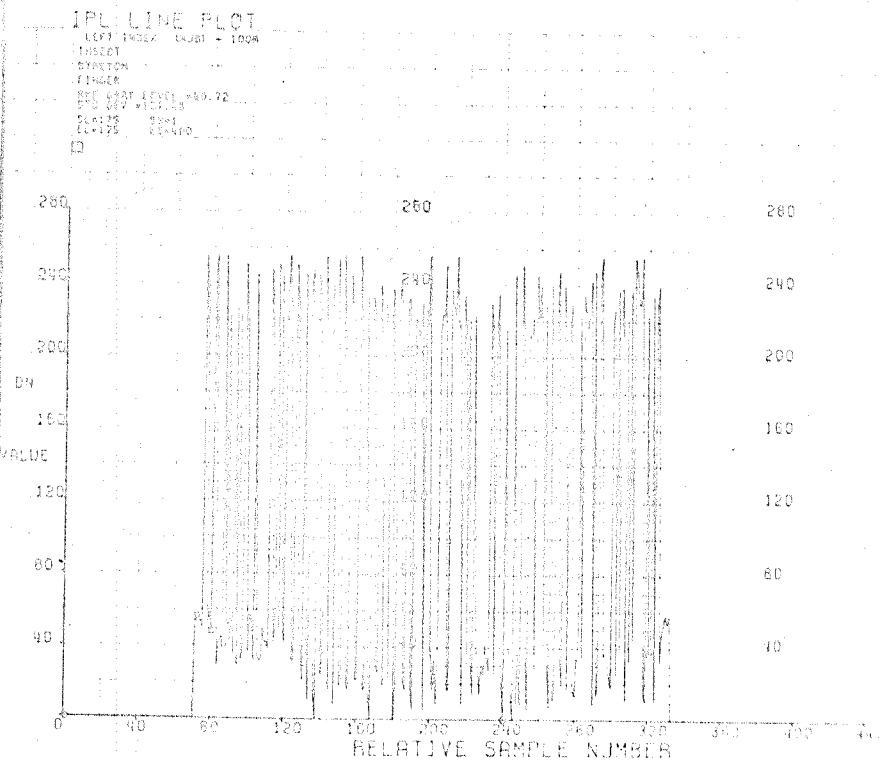


FIGURE 41: Fingerprint Image Enhancements

capable of providing on-the-scene analysis of a urine specimen. The proposal will advocate a gravimetric column capable of complexing the morphine specifically. This morphine complex will fluoresce under ultraviolet light. In addition, the characteristic rate of displacement of the morphine along the column will be measured. These two characteristics, chemical and physical, give sufficient information to identify morphine.

The SRI TATeam will evaluate this proposal with respect to forensic needs.

TV Camera for Remote Surveillance. The Chicago Police Department (CPD) needs a very small TV camera for specialized police surveillance application. For example, the need for a larger, more expensive surveillance helicopter could be minimized by cutting down the weight of the surveillance equipment. The Teledyne Microeye TV camera developed for the Marshall Space Flight Center is a possible solution. The Microeye is a complete self-contained television camera, including all necessary video electronics and high-voltage power supply, yet it weighs less than 2.6 lb, with a volume of less than 34 cubic inches. It was initially developed for viewing of the staging of the Saturn rocket, and for use by astronauts inside their capsule as well as on the moon's surface.

The IITRI TATeam obtained a NASA film showing the camera in operation. The film was shown to the heads of the CPD's R&D Graphic Arts and Communications Departments and some of their key staff. As a result, the CPD has agreed to test and evaluate a unit for police work in sites such as a subway station, expressway, and from a helicopter. The unit can transmit 50 to 100 feet line-of-sight to a portable relay unit.

Assuming successful completion of the tests, the feasibility of obtaining LEAA grants to police departments for use of the camera will be explored. It is entirely possible that such cameras could also be used for specialized industrial and commercial surveillance applications, as well as for U.S. Postal Service surveillance requirements.

Characterization of Glass for Criminalistics. Glass is one of the most important types of physical evidence. For example, fragments of broken glass furnish evidence in many hit-and-run cases, burglaries, and other crimes. After hit-and-run accidents, the glass may be shattered into small fragments making it impossible to reconstruct the original piece. The suspect's car may not be available. To identify the car, the investigator tries to determine the glass characteristics to compare with the known properties of glass used in different makes of cars. The investigator is interested in those properties that vary among brands, and from batch to batch in the same brand. These may include, but are not confined to, refractive index, elementary composition, and hardness. Greater standardization of glass in recent years has made the task of differentiation more difficult, and it is now necessary to detect very minor constituents and characteristics.

In response to an SRI TATeam Problem Statement, a Goddard Space Flight Center (GSFC) scientist suggested that the glass could be identified by determining concentrations of transition and rare-earth element ions using electron spin resonance (ESR) techniques. Nominal detection limits correspond to less than 1 part per million in a 100 milligram sample; actual limits are probably higher.

Representative samples of headlight glass were obtained by SRI, and the GSFC scientist demonstrated the feasibility of this approach. The information is currently being prepared for publication in the Journal of Forensic Sciences. This is an excellent example of the creative application of a known analytic technique to a very difficult criminalistics problem. Improvements in physical evidence identification facilitate the apprehension of criminals, and ease court caseloads by increasing the "guilty" pleas.

Simple Methods of Analysis for Metals and Metal Products. A problem identified by the SRI TATeam as common to criminalistics laboratories is the inability to quickly identify the metallic composition of objects to determine their source. For example, obliterated serial number plates, tool marks, and bomb fragments must be identified to determine the manufacture. Spectrographic techniques are useful but are not available in many criminalistic laboratories. More rapid identification of valid evidence helps to reduce the caseload on both the laboratories and the courts.

Langley Research Center scientists developed a wet chemical quality assurance technique to assure quality fabrication of hardware and maximum safety to personnel in various NASA programs. The technique is relatively nondestructive; it consumes or affects an amount of material equivalent to that removed by a smooth file or cleaning with an abrasive. The technique uses standard chemicals and is rapid, taking less than 1 hour.

The Santa Clara County (California) Criminalistics Laboratory has carefully evaluated the NASA publications (Tech Brief and Technical Support Package) describing the technique and has stated that the technology appears to satisfy their needs. After the TATeam provides standard reference metals, the laboratories will incorporate this NASA technique into their operations.

Portable Device for Recording Eye Motion. When approaching a highway sign, does one read it from bottom to top, or from right to left? Do the colors or the letter sizes, or both, affect the sign's effectiveness? Are flashing lights near a highway sign significantly distracting? Do the effects of fatigue, drugs, and pollution degrade a driver's ability to follow signs and other informative material along the highway? These problems are important to researchers, both in the Department of Transportation highway sign area, and in driver safety.

To study these variables under actual driving conditions, it is desirable to provide a driver with a head-mounted device to monitor eye motion and relate it to the visual scene. Current devices include a motion picture camera with a split view--one of the eye and one of the road ahead--that monitors eye motion. This is sufficient for gross eye movement. However, for information on the effects of fatigue, drugs, or pollution, the physiological variables such as pupil dilation, blink rate, pupil position, and the relationship of these to the mental alertness of the subject must also be studied.

The SRI TATeam found that a table-mounted oculometer (Figure 42) had been developed for the NASA Electronics Research Center (ERC) by Honeywell. The oculometer is an infrared source and a light detector which detects the reflection from the cornea and retina of the subject's eye. This instrument permits highly accurate determination and recording of the eye's movement. It allows more accurate monitoring than the camera approach and permits results

to be processed in real time by a computer. The oculometer is now undergoing further development by the DOT Transportation Systems Center. The improved device will have a small optical head and a much smaller electronic control package.

Sewage Processor for Highway Rest Stops. Most rest stops along major interstate highways, which provide a place to rest and eat and a comfort station, are located in rural areas far from a necessary sewage system although electricity and gas are often available. Means of handling sewage from the comfort station must be developed to avoid damaging the surrounding ecology. This generic problem is common to all states. It was originally presented to the TATeam by the Montana Highway Department.

Oculometer facilitates research into drivers' reactions to highway signs, as well as to fatigue, drugs and pollutants.

Figure 42. Portable Device for Recording Eye Motion

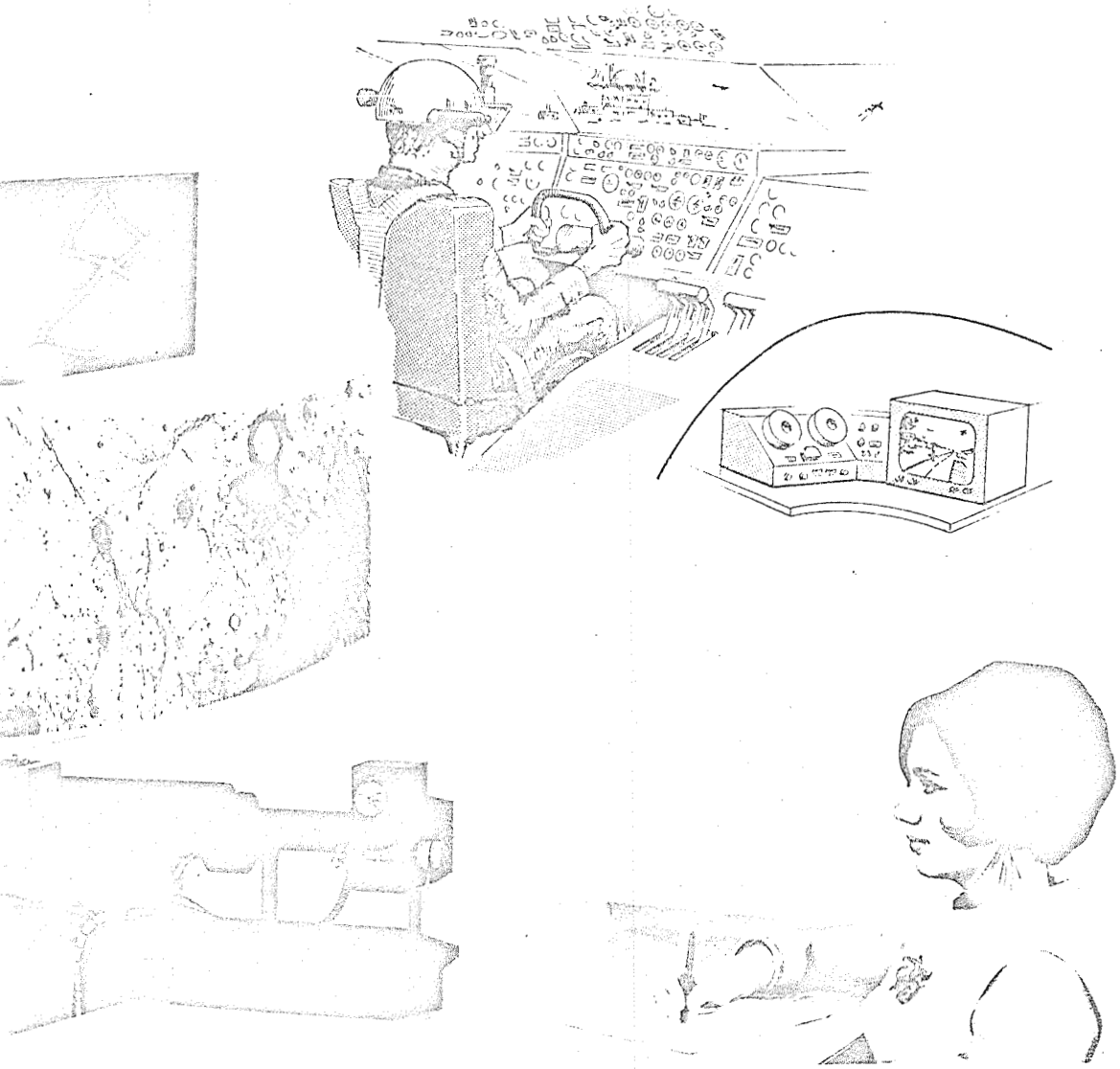


FIGURE 42: Portable Device for Recording Eye Motion

One of the two methods for sewage disposal at rural rest stops such as septic tanks or leeching fields may be ruled out by local health regulations for construction and ground permeability. The second method uses holding tanks and chemicals that require frequent servicing and transporting of sewage to a distant central processor. This is costly and is accompanied by objectionable odor.

A potential solution which overcomes the drawbacks of existing methods is the "Hydro-John" waste management system (Figure 43) being developed for NASA, the U.S. Air Force, and the Atomic Energy Commission by the General Electric Space Division. It was conceived as a waste disposal system for manned spacecraft voyages of long duration--on the order of 180 days. This system uses heat treatment to convert the sewage to unobjectionable products. The contractor and the NASA Field Center that has primary interest are currently investigating the technical and administrative aspects of "down-to-earth" adaptation of this spacecraft system. A second application might be a modified adaptation of the system to a wheelchair for use by retarded children incapable of normal control of body waste functions. In addition, it is of potential use by transportation systems such as railroads and airlines.

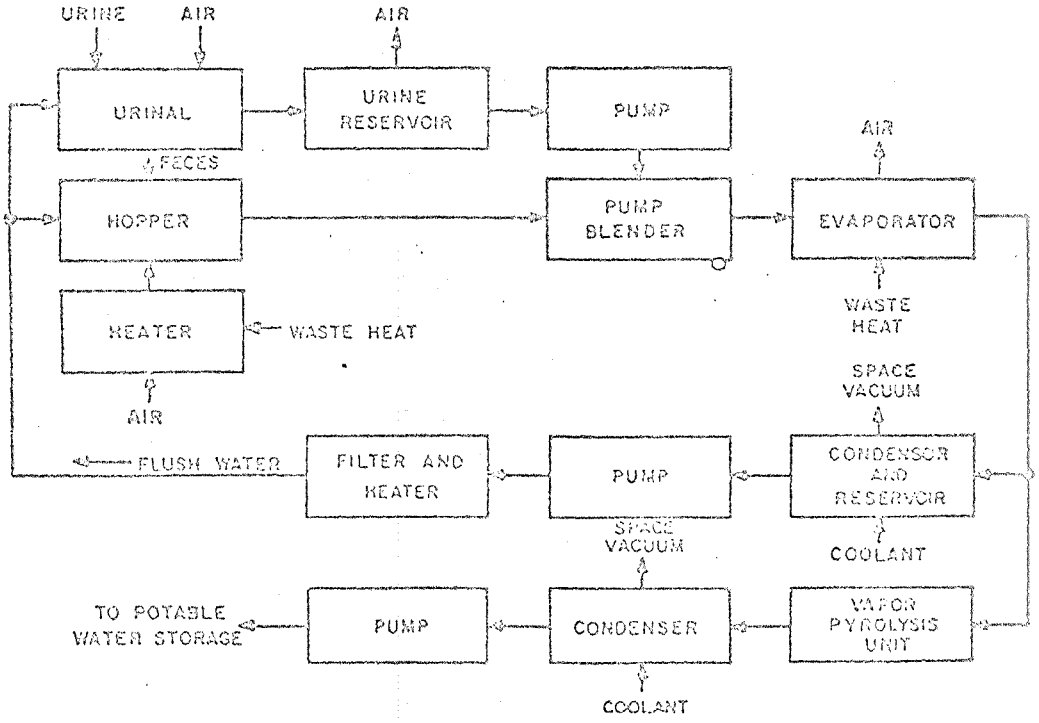
The initial results of this preliminary application have saved the State of Montana $15,000 in research funds. This amount had been allocated to the first phase of a research program before the SRI TATeam made information available to the Montana Highway Department. The first phase of the research program can now be eliminated.

Nondestructive Measurement of the Thickness of Portland Cement and Concrete Pavement. State highway departments require a method to determine the thickness of concrete pavement. A road crew ordinarily blocks off a portion of the highway, then uses special coring equipment to make a number of core holes in the roadway. The retrieved core, when analyzed by the engineer, can provide information relative to the construction and durability of the road surface. However, this is a destructive test which is time-consuming and costly for the state, as well as annoying for the motoring public. A nondestructive method of testing is needed.

The California Division of Highways (CDH), while conferring with the Stanford Research Institute (SRI) TATeam, asked that a study of a nondestructive method for determining the thickness of pavement be made to find applications for NASA technology to assist the CDH. The TATeam distributed the Problem Statement to all NASA Field Centers and consequently it came to the attention of NASA scientists at the Marshall Space Flight Center. Contact between the NASA scientists and the TATeam revealed that a NASA-developed device could measure pavement thickness nondestructively. In fact, a working model was being constructed for the Pennsylvania Highway Department (PHD) at that time. The PHD was carrying out research funded by the National Cooperative Highway Research Program. During this research study, "Evaluating Procedures for Determining Concrete Pavement Thickness and Reinforcement Position," the PHD learned of two NASA Tech Briefs. Tech Brief 68-10183, "Detection and Location of Metallic Objects Imbedded in Nonmetallic Structures," describes a small battery-operated eddy current proximity-measuring device that would detect objects the size of a dime at distances up to 1 foot. The device was used by NASA to measure the thickness of spray-on foam insulation on the NASA Saturn S-2 rocket stage. The second brief, Tech Brief 70-10107,

Fig 43a

Figure 43a. Hydro-John System Laboratory Prototype



Waste management systems of potential use for highway rest stops.

Figure 43b. Hydro-John System Block Diagram

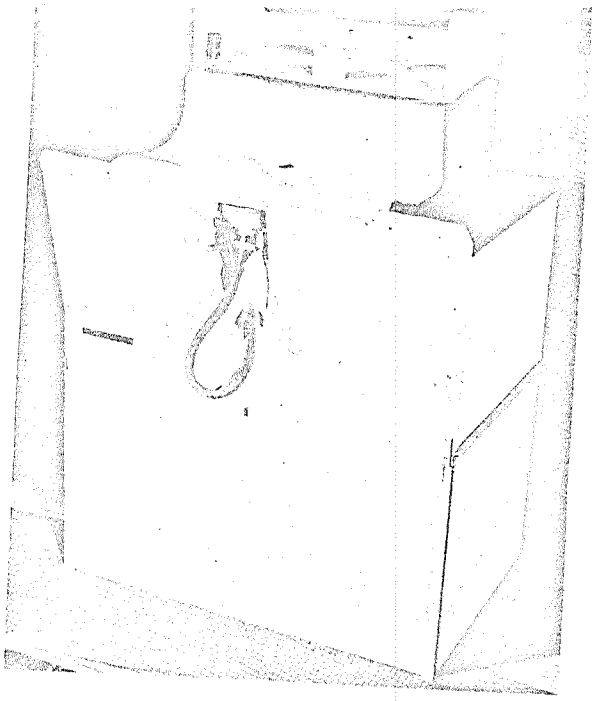
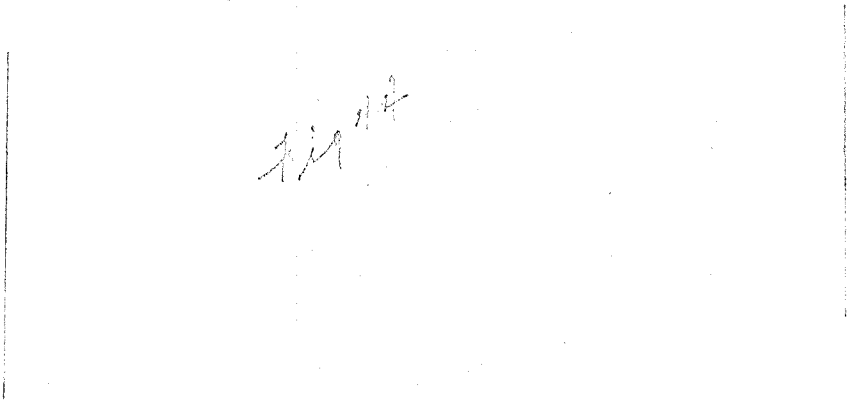


FIGURE 43: Hydro-John Laboratory Prototype (a) and System Block Diagram (b)

"Detection and Location of Metal Fragments in the Human Body," presents a modified version of the eddy current device which can be used for on-site location of ferrous or nonferrous metal fragments accidentally introduced into the human body. The NASA scientists subsequently prepared an instrument (Figure 44) designed specifically to be used for measuring pavement thickness. The device is basically a metal detector which detects a sheet of metal foil laid on the base course before paving. The foil can be of inexpensive metal, 12 to 18 inches square, with a minimum thickness of 0.02 mm. The instrument can be tuned to discriminate between reinforcing rods and the foil.

Multiple tests were made by the PHD with the metal detector on specially prepared test slabs with aluminum plates and aluminum foil placed on the subbase prior to placing concrete. It appeared that the instrument is well suited to detect pavement thickness when steel mesh or fabric reinforcement is used, as in continuously reinforced concrete pavement construction. The metal detector appeared to offer more potential than any other device included in the project. It was recommended that it be included in phase II of the project, wherein instruments will be used on actual construction sites in several different states.

A favorable feature of the metal detector versus other proposed devices is its cost. The NASA designers of the device estimated its commercial cost at about $500. Most other instruments which were being considered in the study cost in the $3,000-$4,000 range. As the potential public market for



Eddy current device detects metal laid on the base course before paving to ensure proper concrete thickness.

Figure 44. Device for Nondestructive Measurement of Portland Cement Concrete Pavements

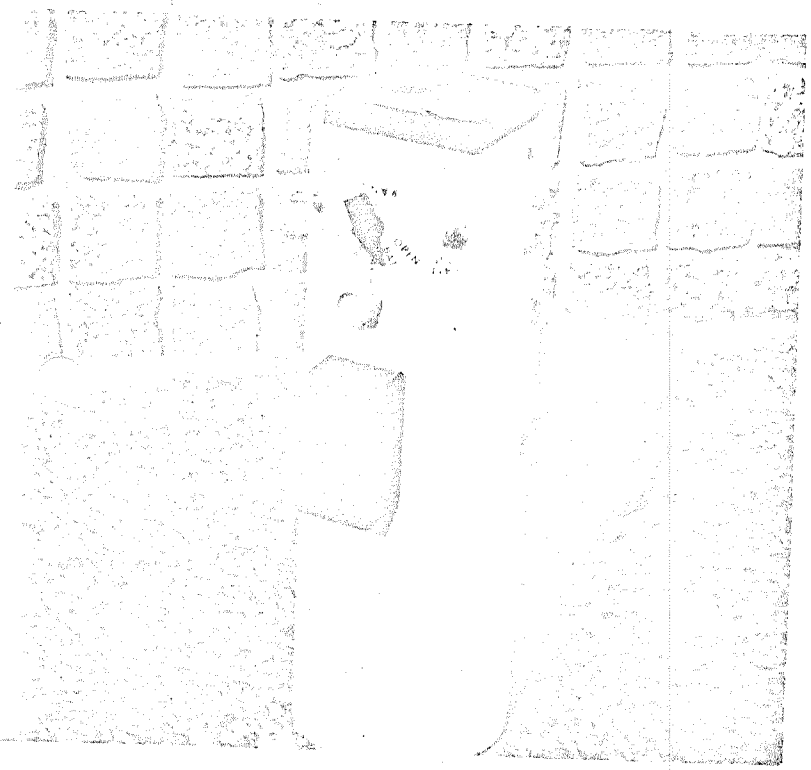


FIGURE 44: Device for Nondestructive Measurement of Portland Cement Concrete Pavements

the instrument is estimated at 20 instruments per state, cost savings to the states would be significant.

Improved Rear Vision Device. Lack of a clear 180 degree rear view from automobiles, trucks, and other vehicles poses a serious safety problem. The use of rear and side view mirrors gives, at best, a partial view of activities occurring to the rear.

The combined use of fiber optics and electronic light amplification, developed at Goddard Space Center, can economically resolve this problem. Identified by the SRI TATeam, the fiber optics system operates in the following manner. A wide angle viewing lens is installed into an aperture in the outside rear of the automobile. To this lens is connected a length of fiber optics rod, sufficiently thick, which extends through the automobile body. The rod leads to a viewing monitor located on the dashboard of the car, directly in front of the driver. The monitor provides a continuous, accurate, 180 degree rear view. At a convenient location along its length, the fiber optics rod is bisected by an automobile battery powered electronic light amplification device. This device amplifies the light image originating from the wide angle lens in the rear of the automobile.

A prototype fiber optics device has been prepared for demonstration to the National Highway Safety Bureau of Washington, D.C.

Concrete Sealant. A surface sealant for concrete is necessary to prevent the admittance of moisture and the associated deterioration of concrete and reinforcing rods. A related problem is that the soundness of structures, especially bridges, is endangered after prolonged exposure to moisture.

A low-cost, long-lasting material which appears capable of solving this problem is a thermoplastic, rubberlike material developed at NASA's Jet Propulsion Laboratory. It was originally developed during a search for a better fuel-binder for solid propellants. The material is prepared by blending a copolymer of ethylene and vinyl acetate with asphalt and a petroleum distillate. The cooled blend is a thermoplastic material having good tensile strength and resilience in the temperature range of 50° to 150° F. The SRI TATeam has requested application engineering funds to manufacture a pilot run of the material for evaluation by the Highway Research Board.

Improved Vehicle Brake Materials. A severe U.S. Postal Service problem is rapid brake lining wear. The SRI TATeam found that Ames Research Center research in brake linings for large aircraft was directly related to the automotive application. Subsequently, Ames scientists formulated and tested a series of composite materials, with variations in amounts of several ingredients, for the purpose of tailoring the friction and wear characteristics to a desirable compromise. Bench tests have shown that the new ablative lining material may have an operational life of four to five times that of conventional brake linings.

Tests on a postal or similar vehicle will be conducted soon at Ames Research Center. In parallel, the SRI TATeam will conduct cost-benefit studies to provide data to support commercialization of the material. These studies will also permit the Postal Service to determine the cost effectiveness of the

new material. If use of the material appears feasible, the Postal Service will conduct tests on postal vehicles in normal service.

The railroads are also interested in new brake materials. Their problem is different in that railroad linings must withstand very high temperatures for long periods of time. Samples of railroad brake shoes have recently been sent to Ames by the Southern Pacific Transportation Company for comparison with the new NASA-developed material. Southern Pacific will work closely with the Association of American Railroads Research Committee on this problem.

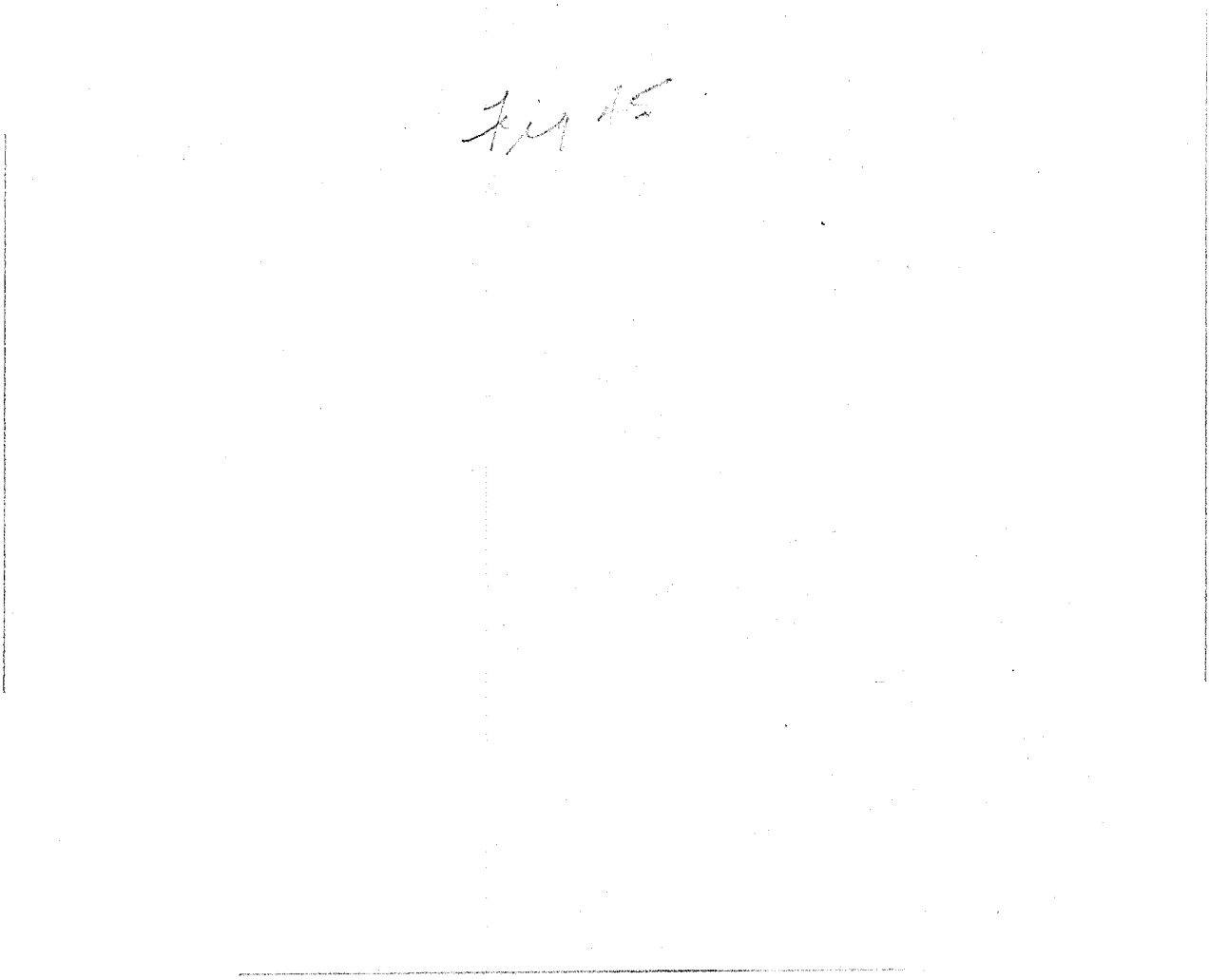
Complex Coordinator Aids Traffic Safety and Air Pollution Research. The NASA Langley Research Center Complex Coordinator (Figure 45) was originally developed to test performance degradation in astronauts exposed to stressful environments. It has also been used on two underwater experiments (Tektite I for 2 months, and the Ben Franklin in the Gulfstream Mission for 30 days). This device was initially recommended by the SRI TATeam as a means of demonstrating to drivers the effect on human motor behavior of drugs, particularly alcohol, and for testing driver response to various air pollutants.

The Complex Coordinator tests driver perceptual and motor skills by requiring continuous arm and leg responses from a test subject. It enables researchers to perform quantitative evaluation of the subject's performance prior to, during, and following normal and programmed abnormal conditions. The system consists of an operator control console, recorder, the subject display panel and limb controls, and associated cabling. When a "problem" is presented by the programmer, it appears on the test subject's display panel as a series of lights. The subject must manipulate hand and foot controls to cause correct illumination of corresponding lights, thus indicating that the "problem" has been correctly answered.

Hand and foot movements are timed and counted, displayed on the operator's control console, and then permanently recorded. A serial reaction feature presents a new problem after the completion of each answer, and a self-paced feature assures that new problems are presented only upon completion of the previous one. Successful problem completion requires the correct positioning of all four hand and foot controls (complex coordination). Psychomotor performance is measured when the subject sees the combination of problem lights and performs the correct action with the limb controls. The test is then completed, and a quantitative evaluation of perceptual and motor skills is made.

Initial transfer activity was performed by the RTI TATeam. Psychomotor performance data using the Complex Coordinator was gathered by experimenters at Duke University, under contract to the Air Pollution Control Office. The "simulated drivers" tested were first subjected to varying concentrations of carbon monoxide, ranging from 50 to 100 parts per million, for 4-hour periods. The onset of degradation was then detected and recorded as a decrease in skill. Tests were repeated with other pollutants so that those causing performance degradation, and the concentration at which degradation occurs, could be determined and recorded. The feasibility of the device has thus been demonstrated for pollution studies.

The SRI TATeam provided the Complex Coordinator for a demonstration of the effects of alcohol on human performance to the California Driver Education



Tests driver perceptual and motor skills by requiring continuous arm and leg responses. It can demonstrate and measure the effect on human motor behavior of drugs, particularly alcohol, and for testing driver response to various air pollutants.

Figure 45. Complex Coordinator

FIGURE 45: Complex Coordinator

Association. The instructors tested the device before and after consuming cocktails, and considered it a good method for demonstrating the adverse effects of alcohol. Discussions are being held with appropriate law enforcement and highway safety organizations to identify resources for further development and use of this technology.

Fireman's Life Support System. The problem of the Fireman's Life Support System (FLSS) originated from the need by municipal fire departments for a reliably functioning breathing device for use during fires. Following a request by the Boston Fire Department to NASA in 1969, the IITRI TATeam performed a study of various aerospace technological developments which, when put together, form an efficient life support system.

The effort has recently been complemented by NASA interaction with the National Bureau of Standards Office of Fire Research and Safety, and the International City Management Association (ICMA). The ICMA has polled its member cities on their FLSS needs and has organized a Fireman's Breathing System Advisory Panel to work with NASA in solving this problem. In addition, the ICMA will serve to aggregate the fragmented city demand for such devices.

The first Panel meeting was held at NASA's Manned Spacecraft Center in June of 1971. The principal problems identified by the Panel in currently used breathing apparatus include insufficient duration, excess weight and size, protrusions, and lack of an adequate air depletion alarm.

In response to the problems that were identified, NASA has proposed two efforts for applying its space background and expertise in life support systems. First, the presently utilized compressed gas demand systems would be reviewed and improved. This would include the development of a lightweight pressure vessel which has the potential for a 30 percent system weight reduction, and the mounting would be changed from the shoulder to a more comfortable hip position. The end product would be a modification kit to improve presently available systems.

As there is little information available on the breathing requirements and environmental conditions during actual fires, NASA has contracted with the Harvard School of Public Health to obtain minute volume data, and oxygen and carbon monoxide concentrations for firemen. This data will be gathered in cooperation with the Boston Fire Department.

The second NASA effort is a proposal to develop a completely new system concept for an optimum fireman's breathing system. This would include a system design analysis, and then the design, fabrication, and testing of a prototype. The system would then be made available to commercial organizations for manufacture and distribution.

These two applications engineering efforts were funded by NASA after the Panel meeting. There will be periodic meetings between NASA and the ICMA Fireman's Breathing System Advisory Panel during the project to assure full communication between the NASA scientists and engineers and the city managers and fire chiefs.

NASA will study the firemen's breathing apparatus using a systems approach similar to that used in the advanced space portable life support system. It

considers the man and the breathing apparatus as a total system, and optimizes the physiological and mechanical relationships of such a system. In addition, NASA has studied many types of life support systems incorporating several different methods of supplying breathing gases for space applications. This includes the development of improved chlorate candles as well as lightweight, high pressure gas systems. Hence, NASA involvement in the development of firemen's breathing apparatus is a logical extension of current space technology.

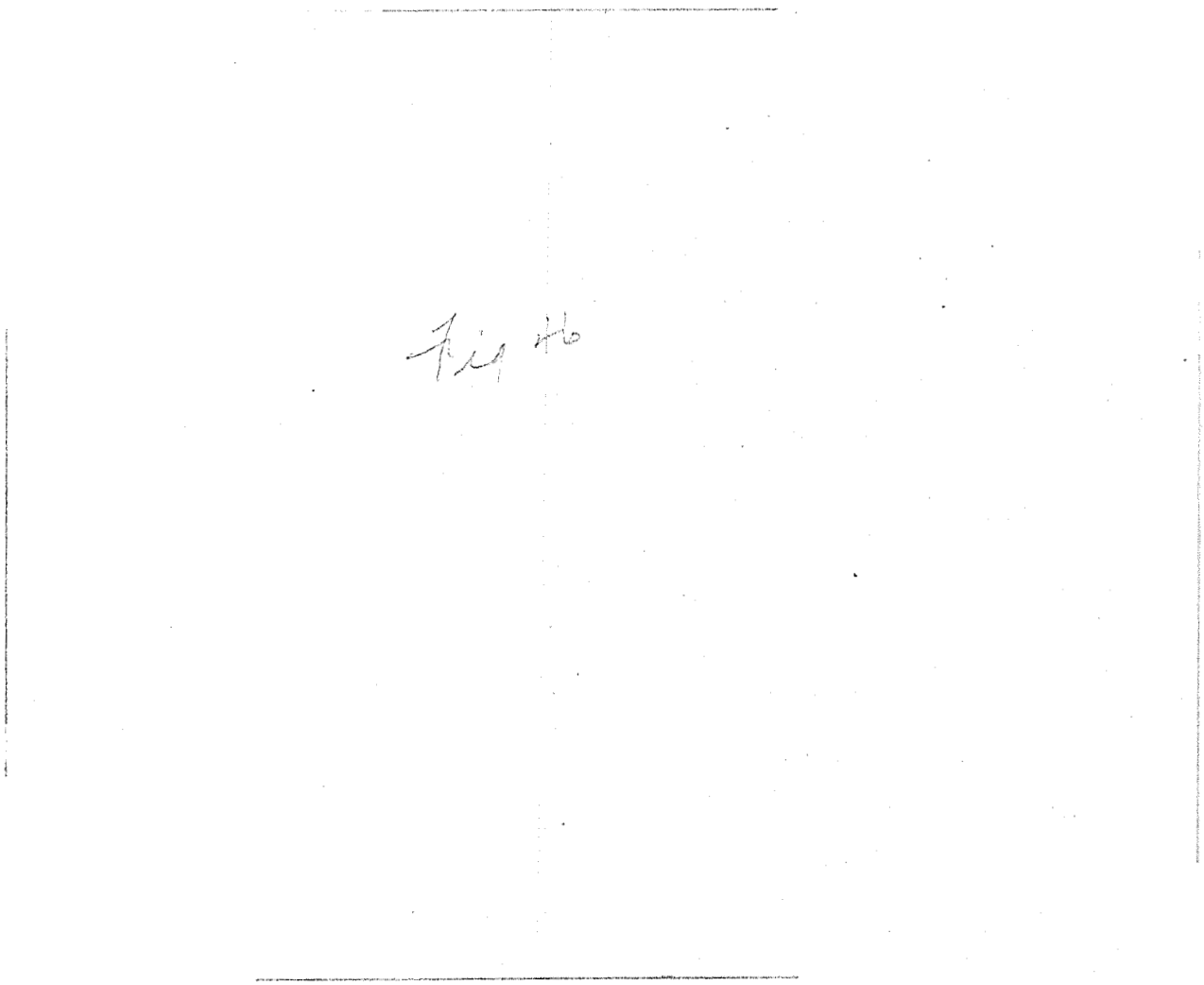
Measurement of the Osmo-Regulation of Blue Crabs. Since the blue crab is important as a commercial source of food, it is important to understand the effects individual pollutants and combinations of pollutants could have on the quality and quantity of blue crabs produced each year. One means of obtaining this understanding is to monitor the adjustment of the internal environment of the crab as a function of external changes. This can be accomplished to a reasonable extent by monitoring the conductivity of the circulating nutritive fluid (hemolymph) of the crab.

The present approach to making these measurements is to sacrifice the crab in order to get enough fluid to use standard laboratory techniques for making conductivity measurements. Since a crab is good for only one measurement, the test must be statistically designed, and requires a large sample size in order to place reasonable confidence limits on the results. There are several difficulties which have, until now, prevented the researcher from instrumenting the crab for continuous monitoring. One difficulty is the crab's aggressiveness which precludes using a wire for signal transmission. Also, conventional telemetry systems will not transmit through salt water.

A system designed by researchers at the NASA Langley Research Center will eliminate the need for large numbers of crabs and will permit obtaining more than one measurement per crab. The system consists of a microminiaturized conductivity probe, power supply, signal conditioning electronics, and a telemetry transmitter. The entire package weighs 2-3 ounces and is 1 square inch in size. It is shown attached to the crab in Figure 46. An important feature is the ability of the system to transmit through several feet of salt water. A receiving antenna and associated electronics will be located nearby, but out of the water, to receive, process, and display the telemetered data as conductivity readings.

During a test of the device, a crab's hemolymph salinity and heartbeat were monitored over a 3-hour period as the salinity for the water was varied from that of sea water to that of distilled water. With the Problem Originator's prior knowledge of the blue crab's osmo-regulating ability, he is confident that the system is generating valid data. The Problem Originator is with the Bureau of Commercial Fisheries.

Successful application of this system will enable the Problem Originator to generate a greater quantity of realistic physiological data over a shorter period of time using a smaller sample size than has been possible in the past. The results of this research are applicable to development of meaningful regulation for allowable pollution levels in estuarine waters. A key to this knowledge is the examination of metabolism in the primary elements of the marine food web. To this end, scientists at the University of Miami's School of Marine and Atmospheric Science have used mass spectrometry in laboratory



Transmitter permits monitoring conductivity of crab's circulating nutritive fluid for research on effects of pollutants.

Figure 46. Crab with Biotelemetry Transmitter Attached

studies of photosynthesis of tropical species of microalgae, as well as cultures brought back from the Antarctic. The former is a highly sophisticated and sensitive analytical technique previously used primarily in chemical and geological research. With it, University of Miami scientists have demonstrated that algae in the sea respire far more rapidly in light than in darkness, a discovery that would have been impossible with more conventional methods of studying metabolism. This discovery is extremely important because all respiratory activity must be substracted from photosynthesis to obtain net estimates of the production of potential food reserves.

The school's mass spectrometer, because of its large size, is difficult to use aboard a research vessel and cannot be used in a submersible craft. In addition, inherent limitations in the design prevent the researchers from measuring more than one of several concurrent biological activities at a time.

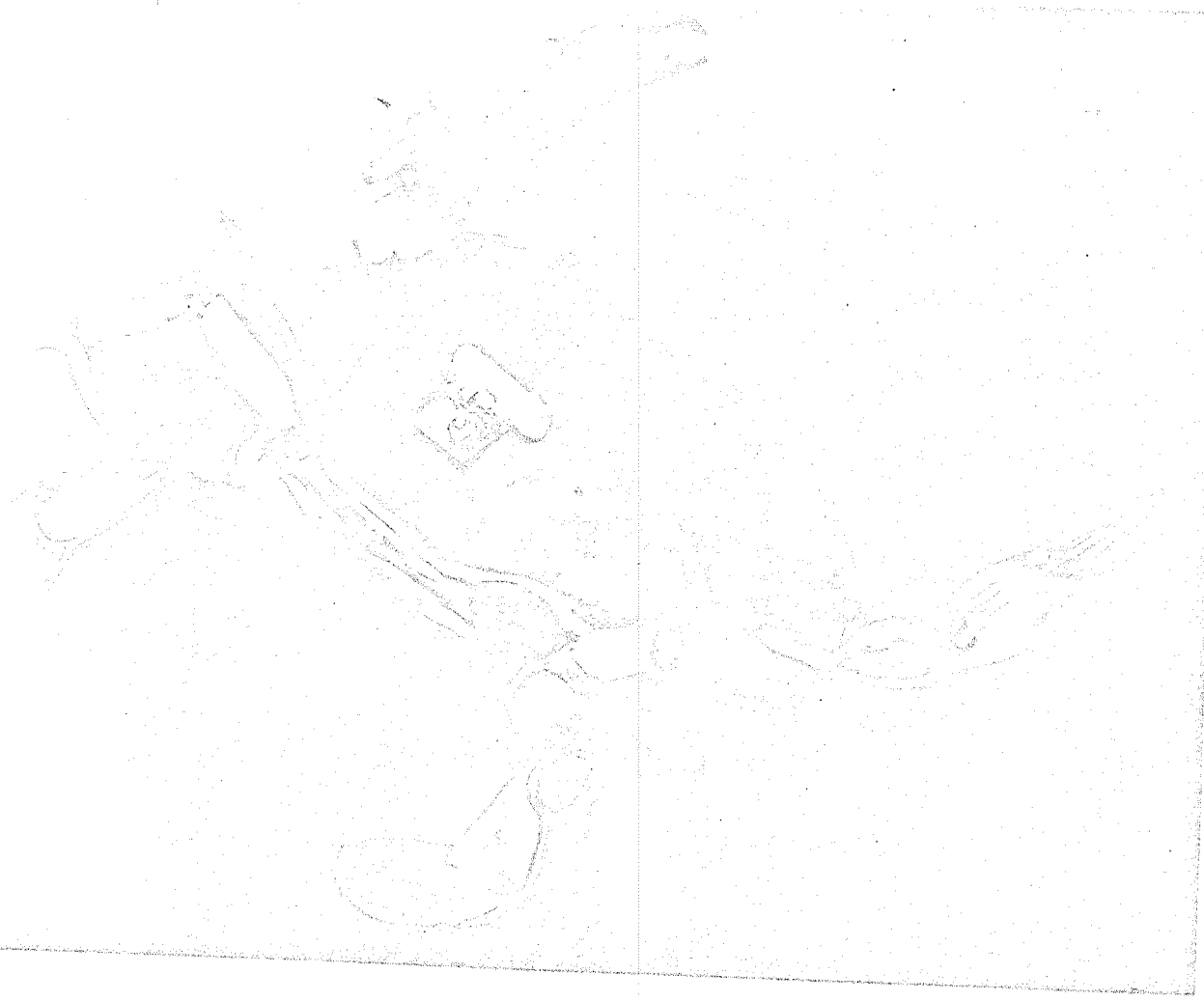


FIGURE 46: Crab with Biotelemetry Transmitter Attached

These problems were overcome with the use of a NASA miniature mass spectrometer which, with relatively minor changes to the ion pump and electrometers, satisfied the needs of the project. It was originally designed by NASA and personnel at Edwards AFB for use aboard high-performance aircraft.

On Sunday, March 21, 1971, this instrument, loaned to the University of Miami by NASA, was taken into a manned habitat on the ocean floor. The habitat, a Perry Hydro-Lab, was operated at a depth of 50 feet off the coast of the Grand Bahamas. This was the first time that a mass spectrometer had been successfully placed in a manned habitat on the bottom of the ocean. In the near future the instrument will again be taken into a habitat and used in the study of photosynthesis. The problem was identified and a loan arranged by the RTI TATeam through the NASA Flight Research Center Technology Utilization Office.

Normally, biological samples collected at various depths and hauled aboard ship experience drastic changes in pressure, temperature, light, and dissolved gas concentration. By having this analytical instrument in a habitat, all of these effects are minimized and the data obtained is more realistic than data obtained in other ways.

There are a number of other areas of research in which a miniature, multichannel, portable mass spectrometer will be of great value. These are currently under investigation.

Reservoir Water Column Density Measurement. Stratification in reservoirs is a cause of water pollution not generally known to the public. Within reservoirs, particularly in the larger, highly stable ones where the water movement in and out is very small relative to the reservoir capacity, considerable density stratification can take place. Stratification is dependent on water depth, temperature, and chloride concentration, and becomes a problem when water in the lower section of the reservoir becomes anaerobic, or depleted of oxygen. This condition renders the water undrinkable, causing a potential water supply problem. Research aimed at solving this problem requires a means of determining the stratification within the reservoir. Early detection of stratification will enable pollution specialists to take remedial action. This dictates a need for measuring the water density throughout a "column" of water in the reservoir.

The IITRI TATeam rapidly located a tentative solution by means of measuring water density. The device is a fluid density analyzer (Figure 47), developed by TRW, Inc. for NASA's Jet Propulsion Laboratory. It uses Archimedes' Principle to measure the buoyant force of a specific volume of displaced fluid thereby determining the density of fluid. The instrument is insensitive to motion, light-weight, portable, and can be used on a sounding line at various depths. Information on the contractor-developed instrument was presented to the Federal Water Quality Administration (FWQA) and the Problem Originator in May 1970. The FWQA evaluated the information and in June of that year agreed that the instrument appeared to have merit as a feasible solution to the water-density measuring problem.

The next step was to obtain a working model for evaluation. This represented a departure from previous approaches. The TATeam had identified a potential solution; a NASA contractor developed the instrument that was considered the potential solution; and a government agency, the FWQA (The Robert S.

Sensor utilizes Archimedes' principle to measure the buoyant force of a specific volume of displaced fluid.

Figure 47. Transducer for Reservoir Water Column Density Measurement

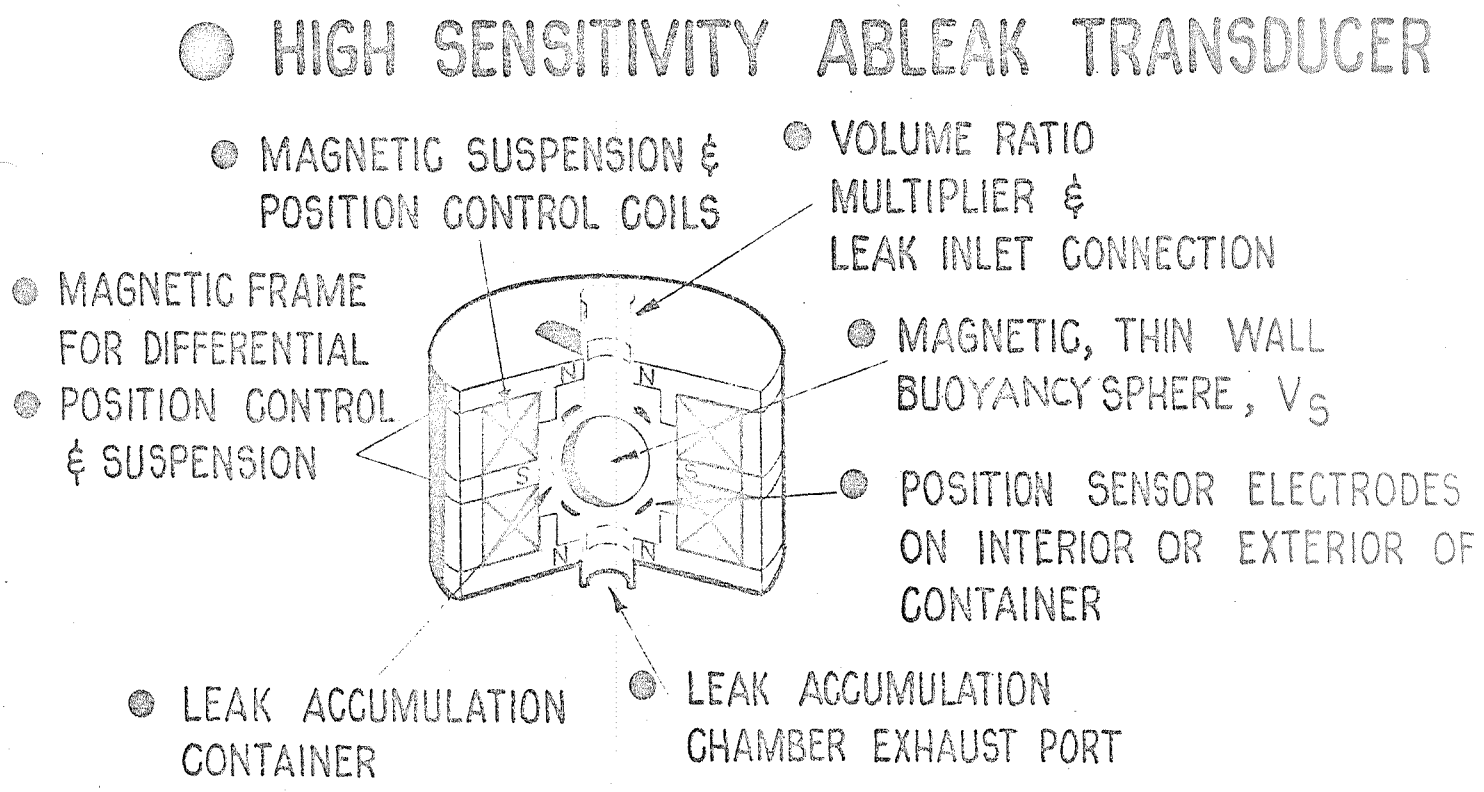


FIGURE 47: Transducer for Reservoir Water Column Density Measurement

Kerr Water Research Center), had agreed that the instrument could be a potential solution to their problem. The Water Research Center, unfortunately, was operating under constraints which did not permit their direct evaluation and adaptation of an instrument furnished by the contractor through the TATeam. The constraints made it necessary for the contractor to submit an unsolicited proposal to the FWQA in Washington to redevelop the instrument for a specific purpose. The proposal was prepared by the contractor in September.

Because of TATeam efforts which led to identification of potential markets for the analyzer, TRW is considering internal funding of further prototype development for this technology.

Current Velocity Meter. This problem was posed by the Federal Water Quality Office as well as other organizations who need an improved instrument to measure small water current velocities in reservoir research and management. The problem has broad implications in the mathematical modeling of lakes, tracking pollutants for legal actions, and predicting river levels for shippers.

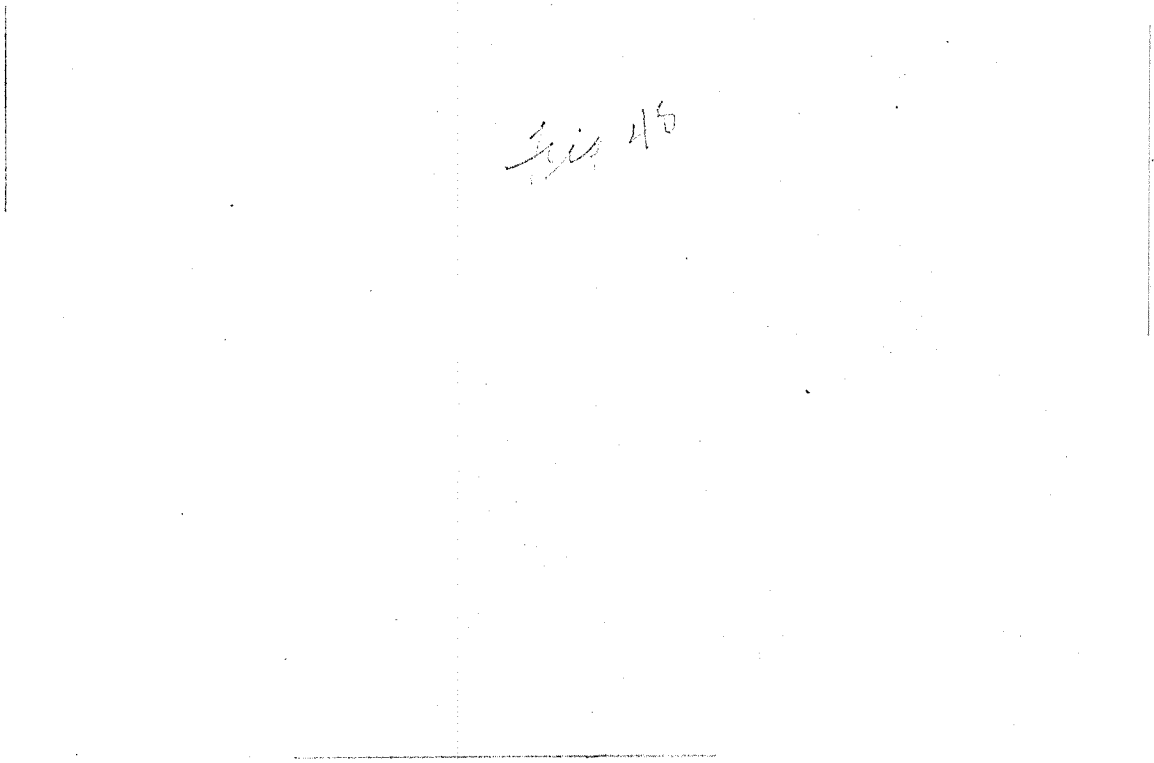
The solution identified by the IITRI TATeam is a water current meter developed by NASA's Langley Research Center. This water current meter was developed to satisfy the need for a relatively simple, inexpensive device to measure generally steady flows characterizing certain near-shore waters. The design is compatible with automatic data acquisition and reduction equipment, so that several meters can be deployed and simultaneously monitored. The meter employs strain-gauge techniques to measure the force exerted on a submerged drag sphere over a flow velocity around the meter.

Presentations to the Problem Originators are now being planned to bring about a rapid application of this novel flowmeter.

Development of Advanced Pollutant Sensor for Total Hydrocarbons. An inexpensive, advanced sensor capable of measuring total hydrocarbons in ambient air, auto exhaust, and stack effluents is needed by the Air Pollution Control Office (APCO) field monitoring program. The instrument would be of great value since it would facilitate field monitoring rather than the costly process of sample collection and subsequent laboratory analysis. At the present time, instrumentation using a flame ionization detector and gas chromatographic techniques are being used. They do not, however, meet the here stipulated requirements.

A device which would simplify and substantially reduce the cost of monitoring equipment for hydrocarbons is an indium oxide, thin-film, combustible gas detector (Figure 48) developed for NASA by the General Electric Research Laboratory. The indium oxide thin-film undergoes a change in electrical resistance when exposed to various concentrations of a combustible gas. The detector is maintained at 400° C, has a response time of about 1 second, and is currently designed to measure concentrations above 500 ppm. The device was designed to detect hydrogen, but the TATeam has demonstrated that it will respond to hydrocarbons and methane.

The RTI TATeam has requested application engineering funds from NASA to conduct a feasibility study using a prototype sensor. This effort is required



Advanced sensor for measurement of total hydrocarbons in ambient air, auto exhaust and stack effluents.

Figure 48. Indium Oxide Thin-Film Combustible Gas Detector

to determine the sensor's applicability to the APCO problem and to identify any modifications.

Wind Tunnel Design Criteria. The accurate measurement of particulate concentrations in smoke stacks, and the design of particulate control systems, requires detailed knowledge of particulate flow characteristics in stacks, and in various collector chamber configurations. As part of its research program in particulate air pollutants, the Air Pollution Control Office (APCO) plans to construct a low-speed wind tunnel. The requirements for the proposed wind tunnel were that it be of sufficient size to allow generation and measurement of particulates at flow rates of from 10 to 120 feet per second. Information was needed to incorporate the best combination of design factors to obtain the optimum configuration, eliminate wall effects, and minimize the size of the tunnel.

Since NASA has considerable experience in wind tunnel design, APCO presented the problem to the RTI TATeam. Information obtained through a literature search of the NASA data bank and through consultation by a Langley Research Center scientist has been used by APCO to specify humidity controls,

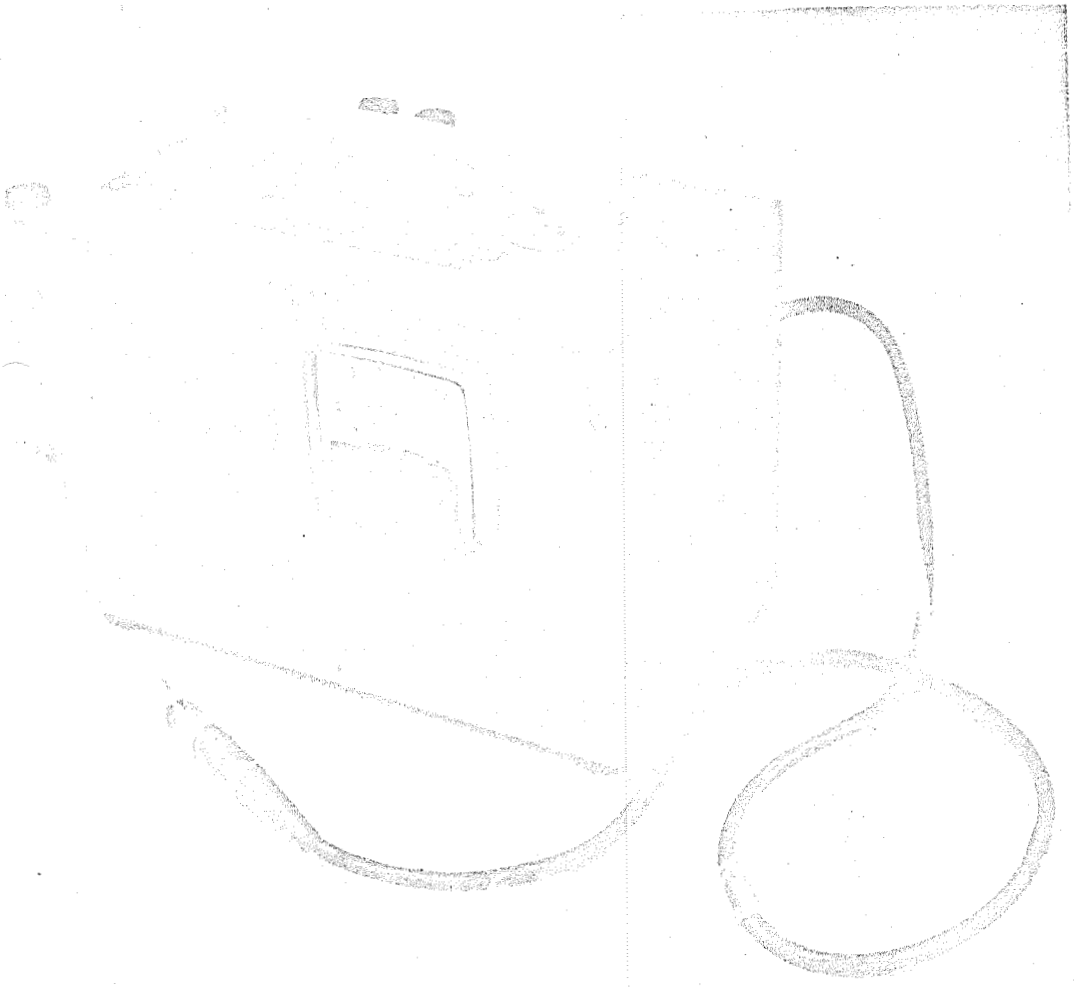


FIGURE 48: Indium Oxide Thin-Film Combustible Gas Detector

combustion unit size, straight vane area, sampling area, dust collections, blower size, and tunnel cleanup procedures for their new units. NASA's experience in the field has enabled APCO to specify system performance criteria which insure that the system they receive will satisfy their requirements. A prototype wind tunnel is now being tested by APCO.

This application of NASA data and technical expertise illustrates a situation in which knowledge and information, rather than a specific piece of technology, plays a significant role in research directed towards solving a public problem.

Direct Measurement of Flame Temperature in Combustion Processes. A need was determined by the Air Pollution Control Office (APCO) personnel to reduce nitrogen oxide emissions from cycling domestic oil furnaces. Although air pollution from a single domestic furnace might be low, the large number of furnaces in operation create a significant problem. The two critical variables which affect formation of oxide of nitrogen are flame temperature and oxygen concentration. Thus, to test the hypothesis that nitrogen oxide emissions can be minimized by selection of proper burner design and flame temperature, the researcher must be able to study and map temperature profiles and patterns in the flame without disturbing the flame itself.

The RTI TATeam conducted a literature search and sent pertinent information to APCO. In a letter of appreciation APCO reported that interferometric holography as described in this information will meet their needs. They plan to purchase instrumentation utilizing these techniques.

Fluidic Flow Sensor for Use in Coal Mine Passages and Sewer Lines. The hazards of working in a coal mine scarcely require a reminder. However, as in many other areas, only a major tragedy stirs the population to action to prevent catastrophes. A recent event was the disaster in 1968 in Mannington, West Virginia, which resulted in federal legislation aimed at reducing mine fatalities and establishing new standards for safety and working conditions. An adequate flow of air through the mine is an important factor that contributes to safety and good working conditions; fresh air for breathing and adquate airflow to prevent accumulations of highly explosive and poisonous methane gas are imperative. Since uniform airflow throughout a mine is virtually impossible, detailed knowledge of the existing airflow is extremely important.

The Bureau of Mines, a Problem Originator, pointed out that a device to measure the air movement is a basic need. Ordinary airflow measuring instruments are not sensitive enough to detect the low velocity wind flow in mines.

A NASA Electronics Research Center scientist suggested that a fluidic air sensor, capable of measuring speeds of less than 10 feet per minute, would be useful in solving the low velocity wind flow problem. Since it has no mechanical moving or electrical components, the sensor (Figure 49) is especially suitable for use in coal mines. Information on this sensor conveyed to the Bureau of Mines was received with enthusiasm. The instrument was developed by the Bowles Fluidics Corporation for the Electronics Research Center (ERC) to be used as an air speed indicator on vertical/shortfield takeoff and landing (V/STOL) aircraft. After further study, the IITRI TATeam prepared and submitted a report to the Bureau of Mines describing the capability of

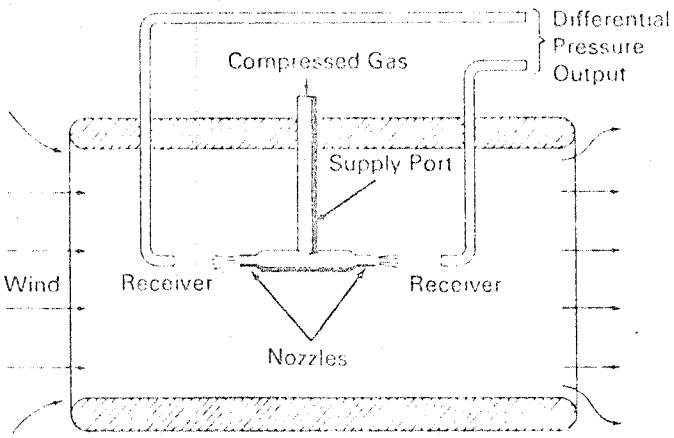


Figure 49. Fluidic Flow Wind Sensor

the NASA instrument for adaptation in mines. The report, Measurement of Airflow Velocities in Coal Mine Passages, was favorably received. The Bureau is currently negotiating a contract for a survey of technologies useful in measuring airflow. The Bowles device will be further evaluated as part of that study.

In many cities, backup and overflow of sewage from overloaded and clogged sewage collection lines is an increasing problem. A method of solving this problem is to monitor sewage flow at various locations in the collection network and to redistribute the load as needed. Accurate and reliable flowmeters are essential to the safe and efficient operation of such systems. Because of the nature of sewage, conventional flowmeters have limited accuracy and applicability.

To solve this problem the basic sensor concept has been extended to measuring water flows. Among the features that make this unit especially suited for measuring sewer flow rates are: (1) the part of the unit submerged in the flow has no moving parts; (2) it is self-cleaning; (3) the sensor is rugged; and (4) it provides no obstruction to the flow. A technical description of a proposed sewage flowmeter was sent to the director of the Dallas Water Utilities by Bowles Fluidics. Dallas Water Utilities has agreed to provide a test site when a suitable prototype is developed.

The U.S. Navy's Office of Naval Research has also funded further development of the sensor. Areas for its use envisioned by the Navy included micrometeorological studies, research in wind dynamics, weather prediction, aircraft operations, toxic gas monitoring aboard ship, and rate of fog dispersal at sea. The device will be especially useful for V/STOL, V/TOL and surface effect craft which maneuver near the ground at very low air speeds.

Detection for Automatic Quenching of Coal Mine Explosions. The Bureau of Mines has been working on a method of quenching an explosion at its point of origin, before it can propagate throughout a mine. Ignition of methane-air mixtures is the cause of most mine explosions. The approach taken for prevention requires a detector which is sensitive to the ultraviolet (UV) radiation emitted from the combustion of methane. The detector must respond within a few milliseconds of the time of ignition, and trigger the dispersion of a chemical quenching agent to halt explosion propagation. A serious drawback to

the system is that it responds to false signals such as those from cap lamps, harmless sparks, and other extraneous sources.

A scientist from NASA's Langley Research Center responded to the need, as defined by IITRI, with a suggestion that a two-channel detector would be able to discriminate between the desired methane signal and extraneous signals. Each channel would be centered on a different portion of the UV spectrum, and the output would be a function of the ratio of the two signals.

Subsequently, experimental measurements were made at Langley using the above concept. The results showed promise and were delivered to the Bureau of Mines who expressed an interest in the concept. The technology may be incorporated soon in a development project to be funded by the Bureau.

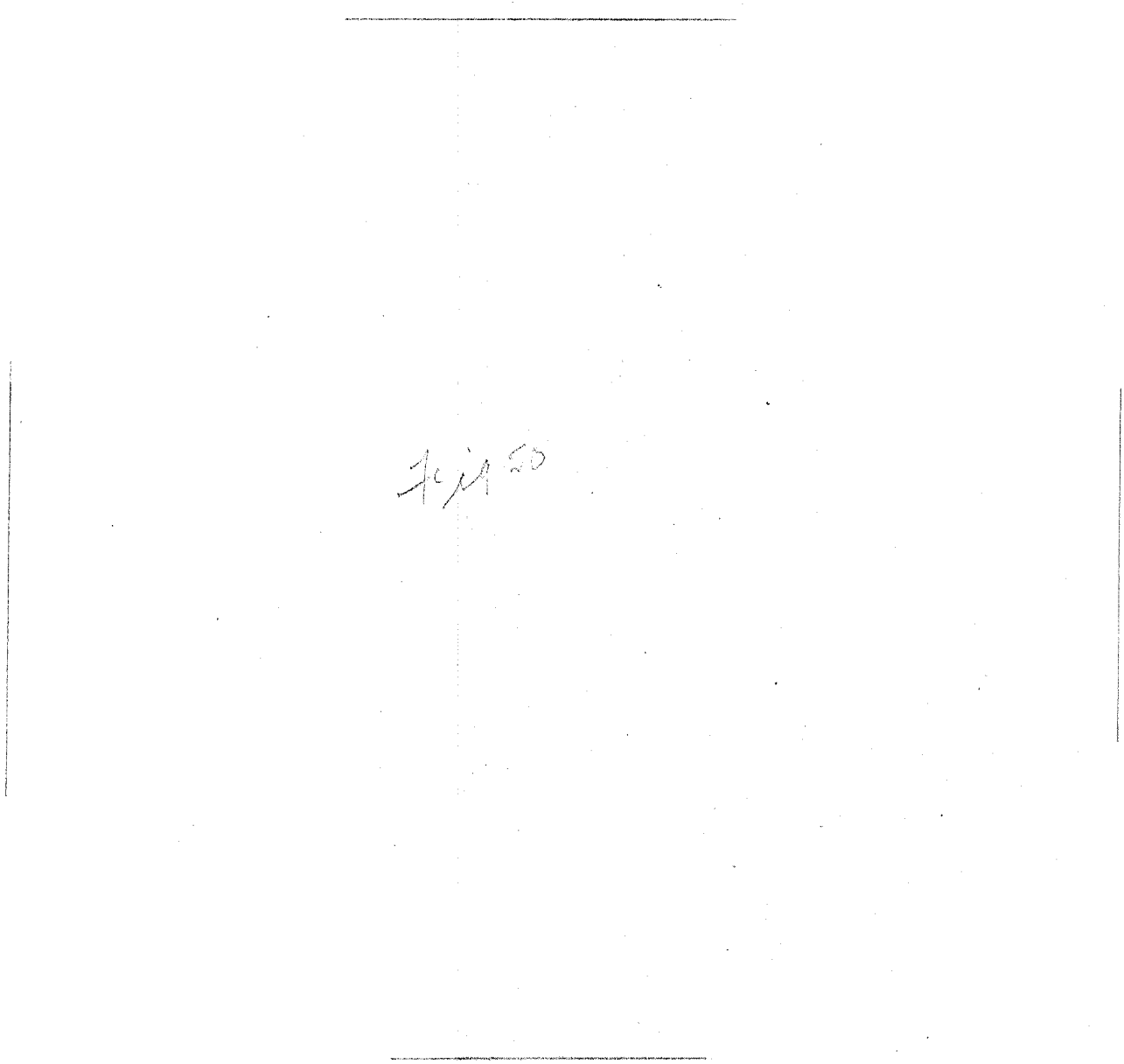
Dust Monitoring in Coal Mines. The airflow sensor device indicates the need for developing instruments specifically to improve both working conditions and safety in mines. Coal dust is an element that can initiate mine explosions as well as aid in propagating methane gas explosions over a wide area. Coal dust is also a major cause of the dreaded "black lung" disease. Recent medical standards established for mine operations require reduction of the level of coal dust within the mine. To meet the standards, the reduction effort will require effective instruments with capacities that current instruments cannot fulfill. This situation established a Bureau of Mines need for a sensor, or particle analyzer, to function as a dust monitor.

In a computer literature search for information related to the Bureau of Mines requirement, the IITRI TATeam located references to a particle analyzer developed for the NASA Electronics Research Center. The instrument (Figure 50), a portable multichannel aerosol particle analyzer, was developed for use in the Apollo Command Module. It is lightweight, compact, rugged enough to withstand takeoff and reentry of the space module, self-powered, and can operate over a wide temperature range. The instrument is also designed to count five particle size ranges between the limits of 0.5 and 10 microns. In the configuration for use in the space capsule, the instrument was in the one-of-a-kind category and expensive.

In cooperation with the NASA Office of Advanced Research and Technology, the instrument was demonstrated to Bureau of Mines officials and scientists. There were mixed initial reactions resulting from the fact that the instrument, as designed for NASA use, could not yield gravimetric readings, nor could it distinguish rock dust from coal dust.

The early demonstrations of the instrument, however, resulted in bringing the need for coal dust monitoring to the attention of NASA scientists, which provided impetus toward the development of the particular technology. A special project was initiated, coordinated by NASA's Office of Advanced Research & Technology (OART).

In cooperation with the Harvard School of Public Health, the OART tested the correlation of the NASA ERC particle monitor with standard mine sampling techniques for coal dust; also investigated were the possibilities of instrument cost reduction and explosion proofing. The OART study personnel interfaced with Stanford Research Institute scientists conducting a study of dust monitoring methods for the Bureau of Mines.



Particle analyzer may permit particulate monitoring to ensure enforcement of new coal mine regulations.

Figure 50. Dust Monitor for Coal Mines

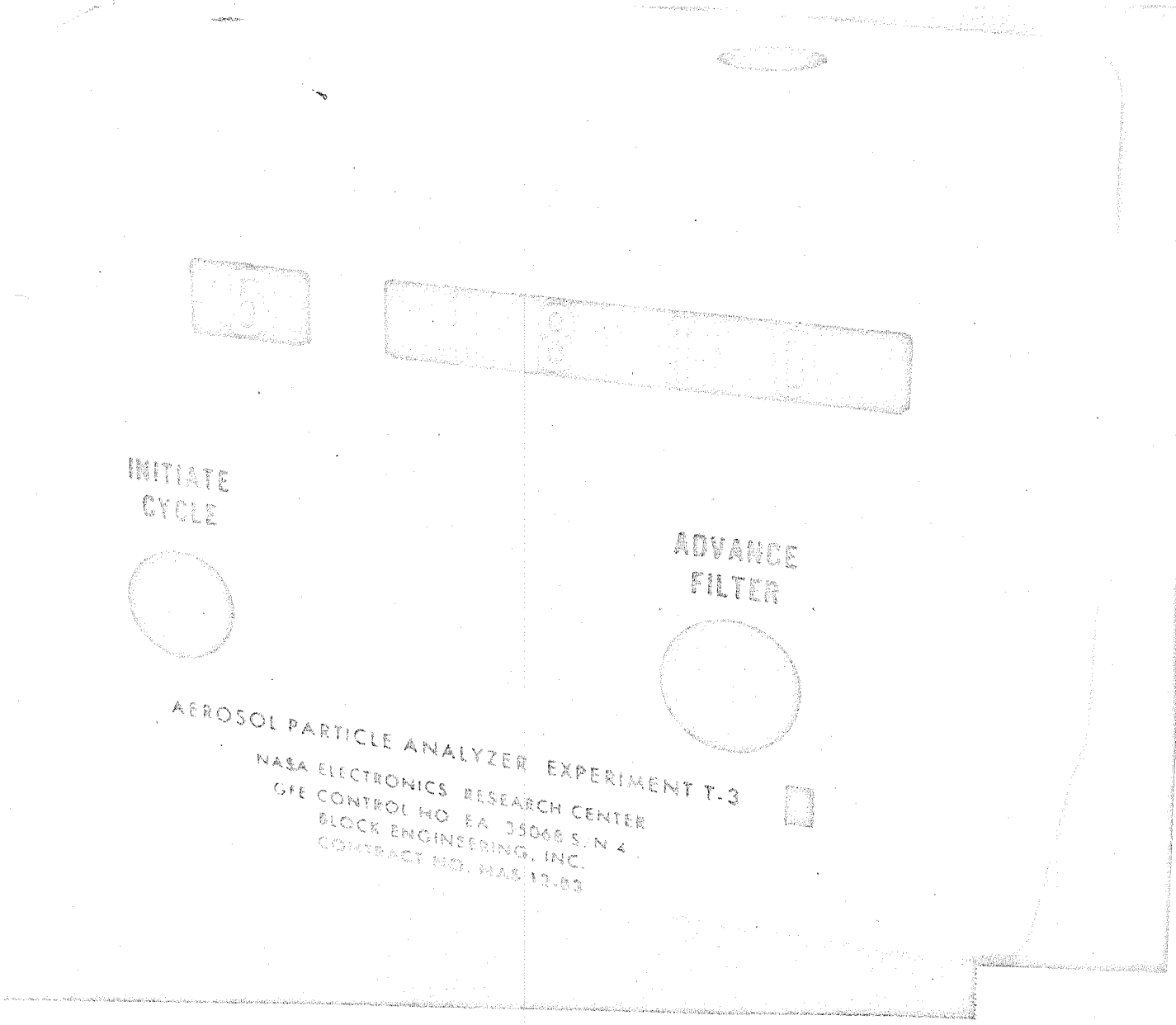


FIGURE 50: Dust Monitor for Coal Mines

The aerosol particle analyzer was accepted completely in principle by the Bureau of Mines in August 1970. NASA and the IITRI TATeam arranged to transfer one copy of the Apollo Model, one breadboard model of an advanced version, and detailed engineering drawings to the Bureau of Mines for use in laboratory experiments.

The Bureau of Mines plans to compare the NASA device against a piezoelectric type monitor also being developed for the Bureau. This evaluation is scheduled for early 1973.

A Methane Monitor for Coal Mines. Associated with detection of methane gas explosion is methane gas accumulations. Methane may be ignited by frictional or electric sparks. To lessen the danger of explosion, the mines must be well ventilated in order to keep the concentration of methane below the lower explosion limit of the gas (5%). When methane concentration exceeds 1.5 percent a mine is considered unsafe, so it is obviously important to determine the actual methane concentration.

The IITRI TATeam located three potential means of determining methane concentration:

(1) An indium-sesquioxide sensor developed by NASA contractors as a hydrogen detector. The principle of operation is based on the change in electrical resistance of the thin-film oxide when exposed to various concentrations of the gas. The device will respond to hydrocarbons including methane, and thus is a potential solution to the methane concentration problem as well as to some air pollution methane.

(2) A W-valve sensor, developed by a NASA consultant, which is a low-priced chromatograph useful in monitoring methane.

(3) A miniature mass spectrometer developed for NASA's Voyager program (Figure 51).

The three suggested solutions were evaluated by the Bureau of Mines, and each was considered to have desirable properties for methane monitoring and detection. The Voyager mass spectrometer has a broader implication to the problem of analyzing the composition of a mine's atmosphere, and has aroused considerable interest at the Bureau of Mines. Subsequently, the Bureau has issued a "request for proposals" for the development of a methane monitor, and has asked that the TATeam discuss the devices with the successful contractor, who would include them in his projected studies.

OTHER TATeam ACTIVITIES

The BAT/TAT Conference. A joint BAT/TAT conference was held in June 1970 with representatives attending from each team, NASA/TUO, the NASA Regional Dissemination Centers (RDC), and George Washington University (GWU). The goals of this conference were to:

Miniature mass spectrometer which can analyze the atmosphere in mines.

Figure 51. Methane Monitor for Coal Mines

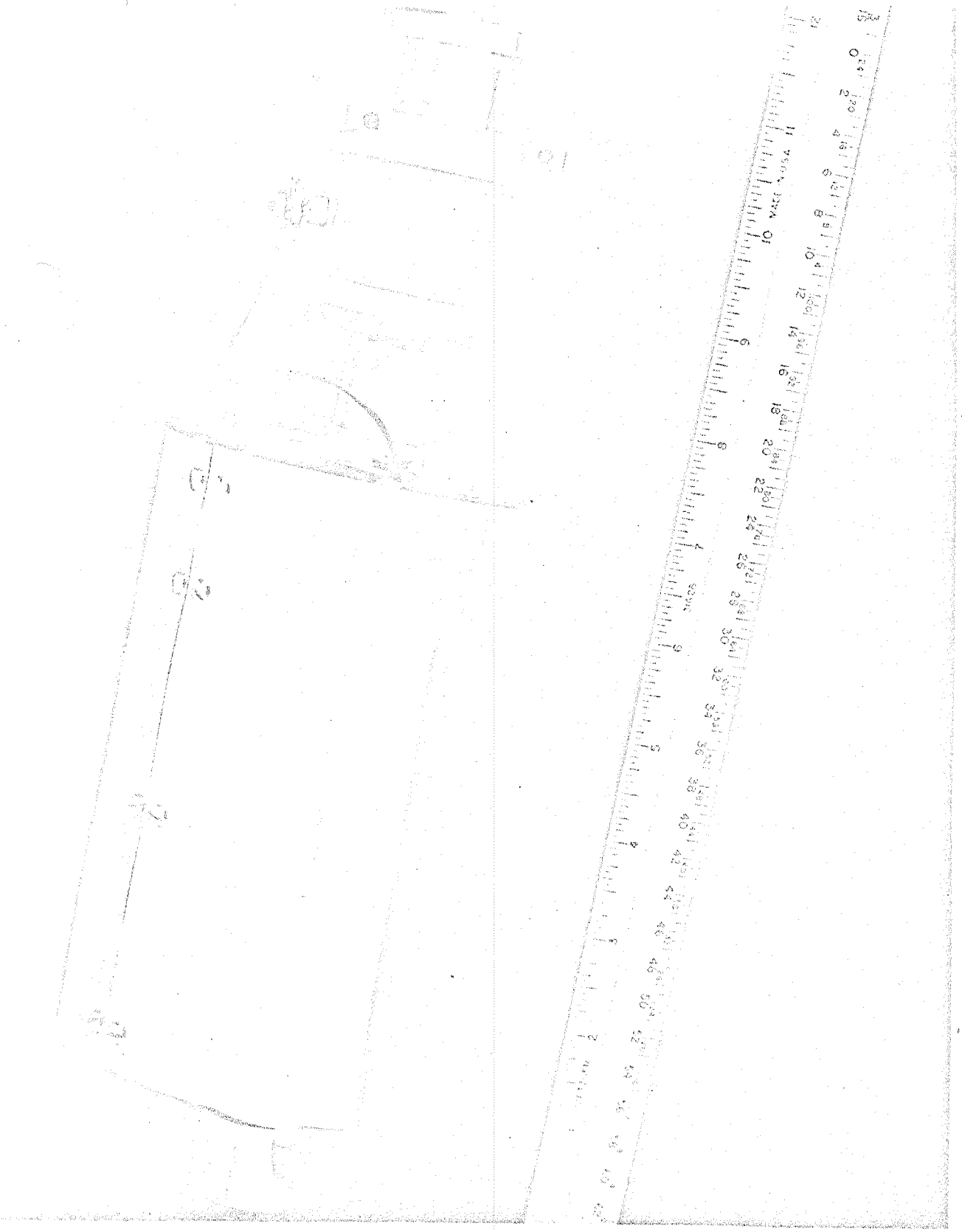


FIGURE 51: Methane Monitor Coal Mines

a. Establish a consensus of the role the team is to play in interactions with the Problem Originator and the solution source.

b. Restate the program goals in terms of program visibility, relationship to national goals, and the operational goal of finalized applications.

c. Develop an understanding of the program's requirements in terms of applications engineering and steps to be taken to secure NASA assistance.

d. Develop an understanding of what constitutes a potential application and the steps necessary to get to the application stage.

e. Develop an understanding of what an application is and how an application may differ from other forms of technology movement across lines. Diffusion and scientific and technical information exchanges are examples of other forms. Restate the requirements for documentation.

f. Understand the purpose for a search.

g. Understand the requirement for operationally valid acceptance criteria, a clear and concise statement of the problem, and an understanding of the specific technological requirements.

h. Discussion of the program goals and problem-acceptance criteria in terms of the place of the team and the RDC in information diffusion.

The conference was successful in terms of the goals outlined. A detailed report was prepared by George Washington University covering the material discussed and the directional implications of the conference. It was given to all attendees by NASA/TUO.

Urban Development Application Team; Federal/State Agency Cooperative Efforts. Some selected activities are highlighted in the urban development effort:

a. The Abt TATeam and the Department of Housing and Urban Development (HUD) have agreed informally that it would be beneficial to both if one of the TATeam's members would work part time directly with HUD's Office of Science and Technology. The designated team member will be located at HUD for the specific purpose of facilitating problem identification and providing rapid response. This arrangement will enable the TATeam to identify problems early with higher specificity. It will also further development of the experiment aspects of the TATeam program.

b. Building Research Advisory Board/National Academy of Sciences. The Abt TATeam described their process for technology application to the Building Research Advisory Board of the National Academy of Sciences. As a result, a meeting was set up with the Building Manufacturers Research Councils (BMRC) for the summer of 1971. The purpose of BMRC is to fill the need expressed by representatives of the building industries manufacturing segment for a means whereby research programs appropriate to the industry as a whole could be determined. Advice would be made available regarding the best method for carrying out such research programs. Information from these programs would then be distributed.

c. National Bureau of Standards. Presentations were given by the Abt TATeam to the National Bureau of Standards (NBS) to introduce NBS to the resources available to them through the NASA program. The NBS is preparing standards and doing testing for HUD's Operation Breakthrough. The NBS will also assist Breakthrough by helping to solve technical problems and by evaluating fire/life safety design factors. The following problem areas and applicable technology have been defined.

(1) Heat transfer in buildings--NASA dynamic heat transfer programs would add to the NBS computer program for heating/cooling load determination.

(2) Quality of indoor air--NBS would like to have ways of measuring gaseous pollutants and particulate contaminants, measurements which NASA has made in aerospace situations.

(3) Energy conservation in buildings--NBS is interested in identifying ways to reduce total power requirements of buildings.

(4) Physiological requirements of buildings--NBS is working on the minimum standards for design criteria.

(5) Improvements in control of mechanical systems.

(6) Computerized prediction and design capabilities for environmental engineering.

(7) Measurement devices--NBS would like sensors and devices that can be assembled in a modular fashion to measure noise characteristics, temperature, humidity, air movement, contaminants, and so on. They also need to be able

to measure synergistic effects of multiple parameter variations.

(8) Earth heat transfer--NBS would like to define heat transfer characteristics of certain soils.

d. Close cooperation has developed between the Abt TATeam and the highly innovative New York State Urban Development Corporation (UDC). The UDC has the major responsibility, and complete and continuing authority, for development of housing projects from land acquisition to final construction. The UDC is building 43,000 housing units per year in New York State. With this comprehensive responsibility, the UDC can adapt innovations to projects, even when innovations may not comply with, or differ from, existing housing codes or zoning regulations. Consequently, cooperation with UDC provides a fortunate opportunity to introduce concepts which in the past might not have received consideration, regardless of merit.

e. United States Postal Service. Abt TATeam personnel have established a working relationship with Postal Service representatives. Several problems are being considered:

(1) Fire protection for postal building nonwet fire extinguishing systems that will not damage mail or people are desirable.

(2) Techniques to prevent fire spread through shafts that carry mail from one floor to another.

(3) Equipment to match heights of delivery trucks and platforms.

(4) Terminal doors that can accommodate any size truck and seal the building and personnel in inclement weather.

(5) Means of reducing noise pollution in postal buildings.

NASA-Technology/Urban Construction Conference. A seminar conducted by the Abt TATeam proved to be of significance. It was directed toward facilitating application of technology to the housing construction industry and determining the barriers to effective application. To accomplish these goals, the TATeam brought together various interested industry representatives and NASA technologists, to introduce specific NASA technology by presenting a basis on which to decide further pursuit of technology applications. Two NASA technological areas provided direction for the seminar: flat conductor cable technology, and the application of polyurethane spray foam.

The purpose of the seminar was to determine:

a. How NASA aerospace technology can be used to help solve urban construction problems.

b. What the major barriers to technology transfer are.

c. If small conferences and seminars can break down some of these barriers and facilitate the transfer process.

The seminar was evaluated as an effective means of accelerating the application process. The TATeam made recommendations for future seminars based on its experience. The seminar that was held and the recommendations that were made were reported by the Abt Associates, Inc. in the publication, The Application of NASA Technology to Urban Construction, in May 1970. The seminar made significant contributions to progress towards technology application efforts in low voltage switching and fire protection/life safety.

Urban Development Application Team; Technology Applications Methodology. The Abt TATeam has developed a technology applications methodology which provides the flexibility to respond to real-life barriers and existing institutions in the very complex and fragmented building industry. Yet the methodology is systematic in nature: it assures proper consideration of all the elements and process actions required for effective and rational application of new technology. The basic "process flow" is illustrated in Figure 52. The TATeam follows a parallel path approach: one set of actions deals with the "market" side of the industry; the other set deals with the technology side; and there are key decision points (problem-solution match, market opportunity) in the process to avoid wasting effort if a problem-solution match fails to meet market needs.

Figure 53 illustrates where within the elements of the building industry the steps of the process flow actually occur. The numbers in the element boxes refer to the actions of the process flow, Figure 52. As is apparent, the Application Team Elements provide a goal-oriented focal point between the building industry and NASA technological resources.

While the preceding figure very simply represents the building industry, in reality the industry is quite complex and highly fragmented. Figure 54 details the industry elements and their basic roles relative to the application of new technology. The complexity of these interfaces and roles precludes a discussion here of even this simplified model of the industry. It is sufficient to note that the technology applications methodology previously discussed has evolved into a form necessary to deal with the realities of this industry. Because of the country's dire need for more new and improved housing, and the gigantic social and economic impact of housing supply and quality, this improved ability to supply new technology to the industry needs is one of the most exciting, promising, and innovative challenges the NASA program now faces.

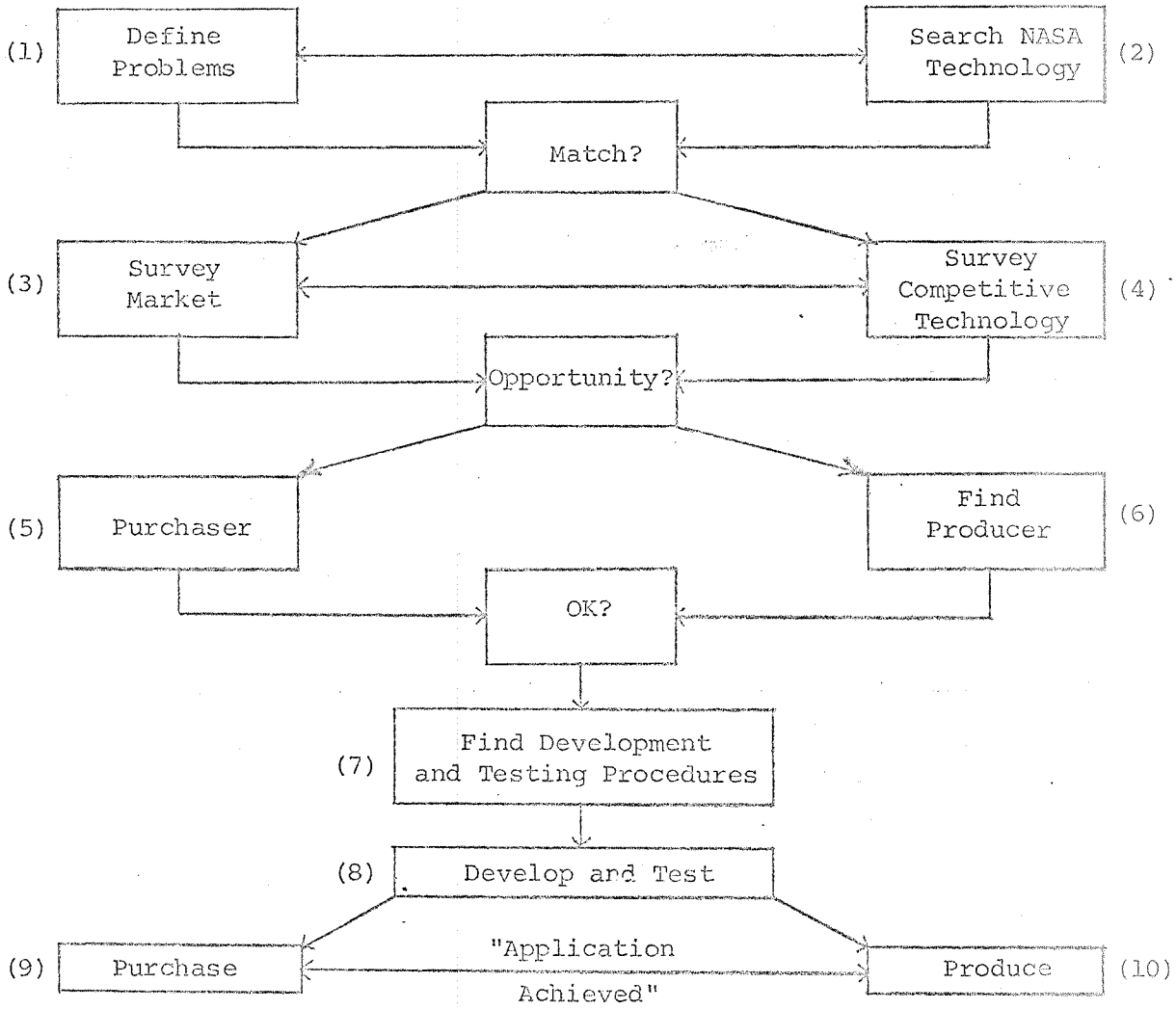


Figure 52. Urban Development TATeam Process Flow

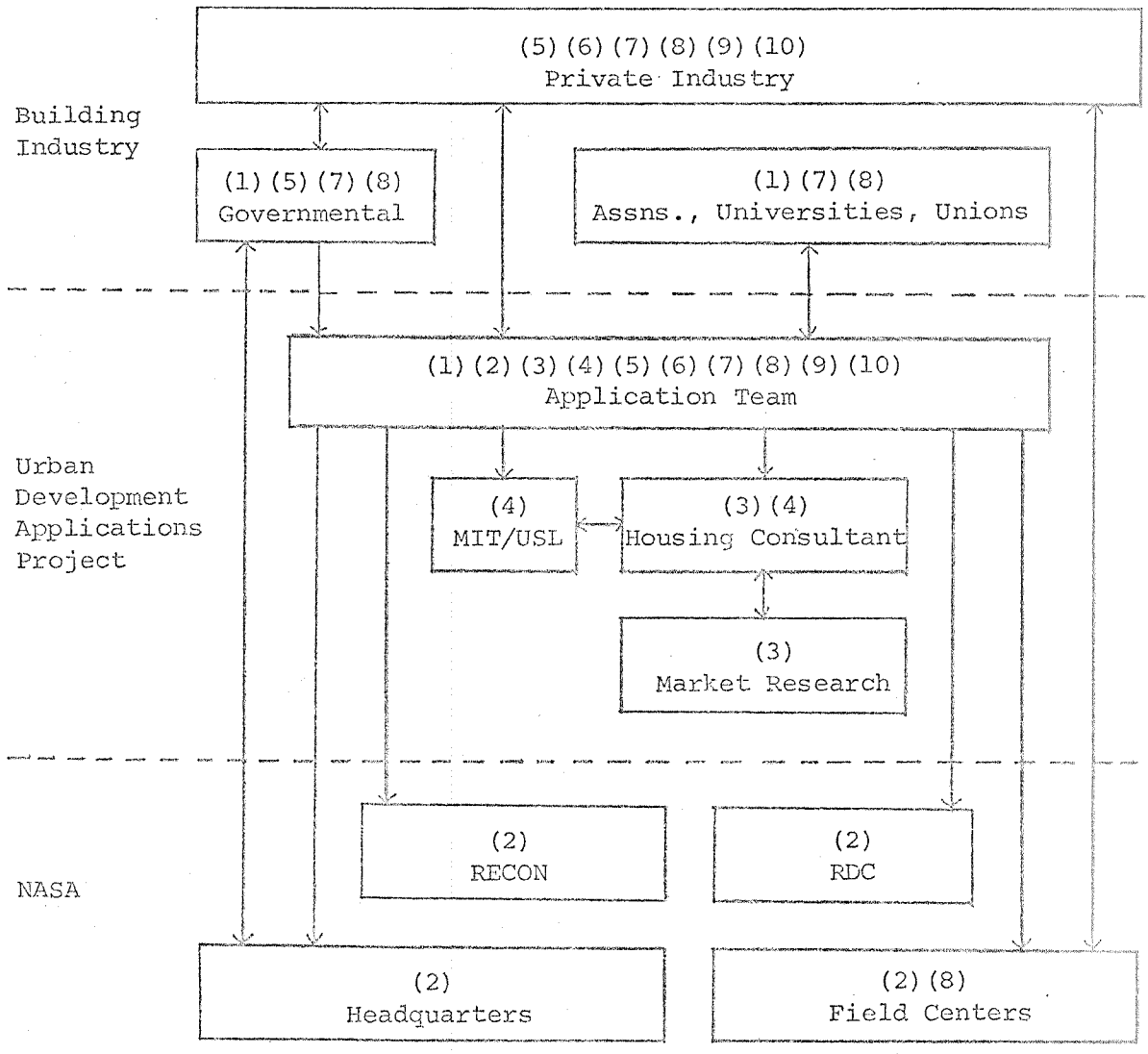


Figure 53. Urban Development FATeam Process Elements

Fig 54

Figure 54. Detail of Interfaces in the Building Industry

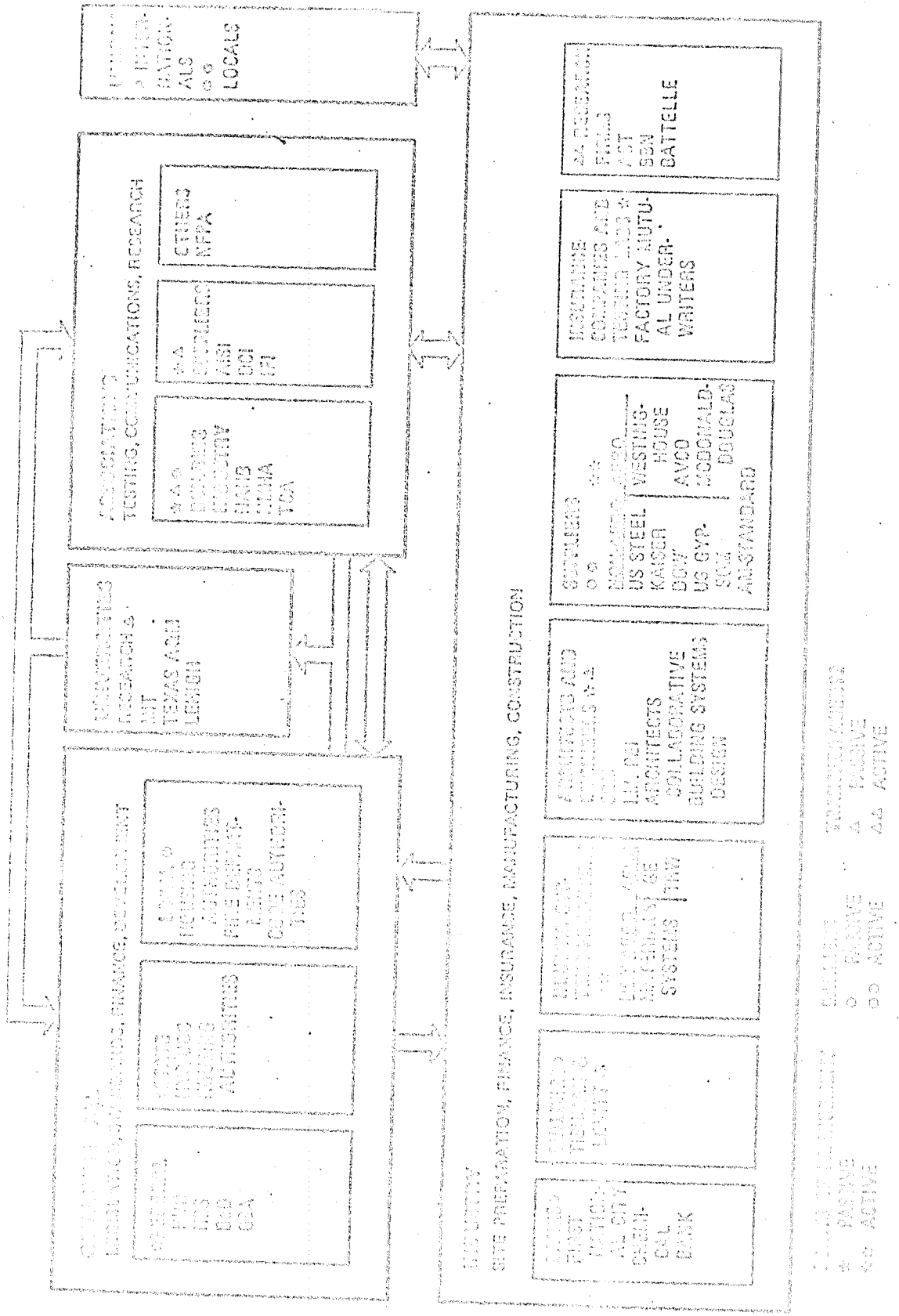


FIGURE 54: Detail of Interfaces in the Building Industry

SUPPORTING ACTIVITIES

SUPPORTING ACTIVITIES

A number of individual activities strengthen the overall efforts of the Application Team. These special studies and projects are briefly described here to help provide a well-rounded picture of the program.

NATIONAL ACADEMY OF ENGINEERING (NAE)

The NAE's Committee on the Interplay of Engineering with Biology and Medicine (CIEBM) has undertaken a "Study of Aerospace Technology Utilization in the Civilian Biomedical Field." The Study is being accomplished through the NAE Subcommittee on Technology and Systems Transfer, chaired by Dr. David Rutstein of the Harvard Medical School. This is a one-year NASA-sponsored effort designed to:

- Identify aerospace engineering technology which appears relevant to specific technological requirements in the biomedical field.

- Relate the biomedical requirements to identified engineering technology in a manner which will facilitate follow-on activities by NASA at its option.

- Provide expert professional advice concerning initiation of specific projects identified in the preceding activities.

- Identify and recommend to NASA interfaces with the mission-oriented organizations on a continuing basis that will contribute to furthering the goal of transferring engineering technology to biomedicine.

The block diagram in Figure 55 illustrates the basic tasks to be carried out in this study.

After an initial familiarization pericd, the Subcommittee created three *ad hoc* groups to focus their study efforts on the areas of *cardiovascular care*, *pulmonary care*, and *remote diagnosis and treatment*. Each of these groups prepared initial statements identifying significant medical problems amenable to technological solutions within their specialties. They have reviewed and evaluated a wide variety of current NASA projects and technologies related to biomedical technology. Problem identification and technology review were facilitated by attendance at selected conferences and meetings and by field trips to NASA field centers. Based on their correlations of needs and available technology, these groups have submitted a tentative set of recommendations concerning further concentrated development of specific NASA biomedical technology of significant potential to the biomedical community. The groups will also suggest means by which the application process can be improved.

The first specific Subcommittee recommendations currently being pursued are the further development of mass spectrometers and fluid flow sensors. The Subcommittee's *ad hoc* group on pulmonary care recommended that mass spectrometry technology could provide a substantial contribution to clinical care.

fig 55

Figure 55. NAE-Aerospace Technology Utilization Study--Functional Diagram

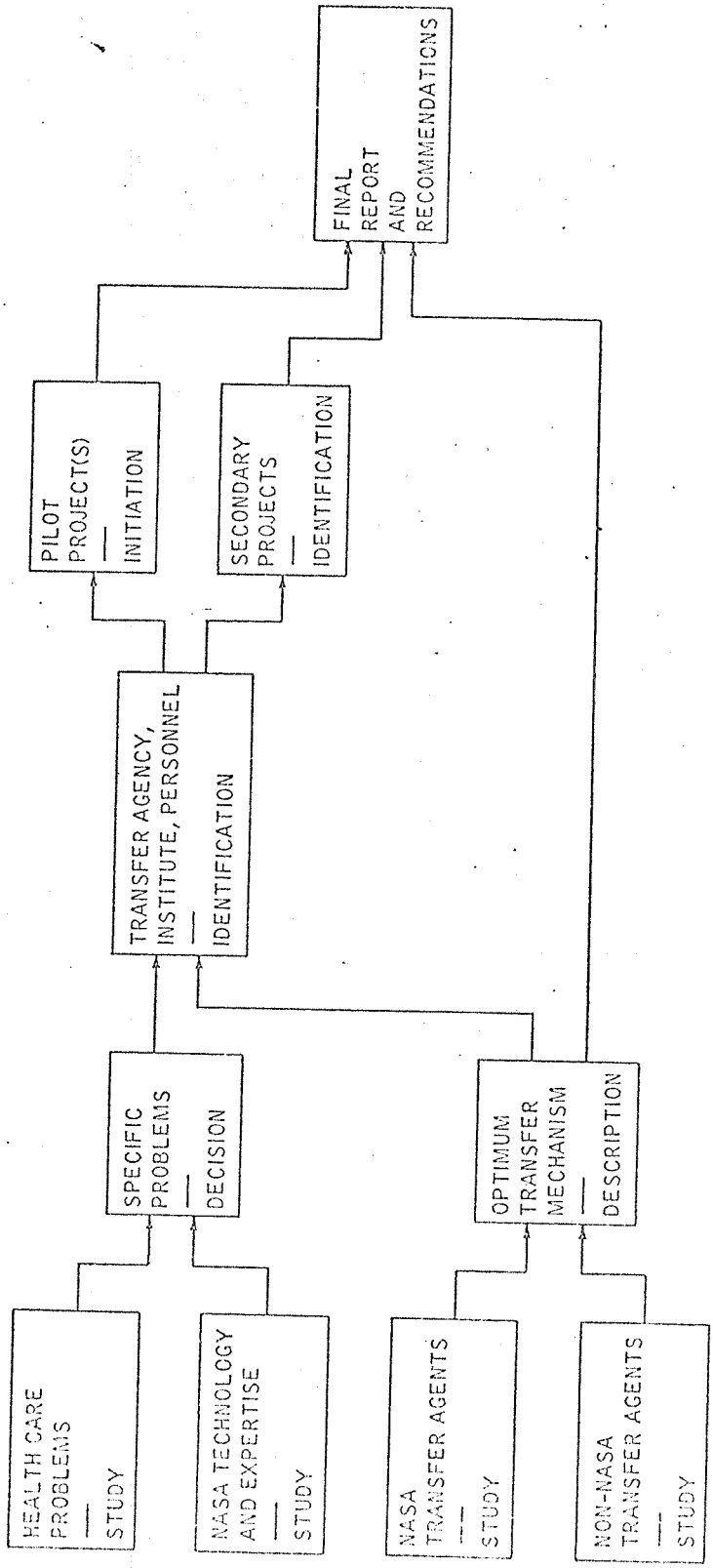


FIGURE 55: NAE--Aerospace Technology Utilization Study--Functional Diagram

The accurate and continuous monitoring and analysis of blood and respiratory gases have been handicapped by unstable and unreliable instruments, short component lifetime, inflexibility, and high costs. Through the efforts of the Subcommittee, HEW's National Heart and Lung Institute (NHLI) and National Center for Health Services Research and Development (NCHSR&D) have expressed an interest in pursuing a joint program for further development of such instrumentation.

The pulmonary care group further recommended that two NASA-supported developments, the fluidic flow air speed sensor and the modulated frequency ultrasonic flowmeter, be further developed to provide advanced flow sensors for continuous breath-by-breath analysis of respiratory flows.

SURGICAL SUITE CLEAN ROOM TECHNOLOGY

As a result of a recent surge of interest in laminar flow clean room systems for use in operating rooms, NASA sponsored a symposium on Clean Room Technology in Surgery Suites. The conference was held at Kennedy Space Center May 21-22, 1971, and included presentations by experts in clean room technology and by doctors currently using laminar flow clean room surgery suites. Topics for the first day included:

- Microbiology of Surgery Suites
- Principles of Laminar Airflow Systems
- Use of Total Horizontal Laminar Flow Systems in Surgery
- Use of Total Vertical Laminar Flow Systems in Surgery
- Use of Vertical Laminar Flow System Over the Operating Field
- Procedural Considerations and Hospital Engineering Requirements for Use of a Laminar Flow Operating Suite

The second day of the conference consisted of a forum on the applications of clean room technology to surgery suites. Problems and potential solutions were discussed. The conference and its Proceedings will provide the impetus for the wider use and greater impact of these highly sterile surgery suites. The conference plans were prepared by the Midwest Research Institute Biomedical Application Team which recently assisted the Washington University Department of Cardiothoracic Surgery in the construction and evaluation of a laminar flow surgery suite designed on the basis of NASA clean room documentation.

ENGINEERING IN MEDICINE-BIOTELEMETRY CONFERENCE

The National Academy of Engineering and the National Aeronautics and Space Administration are cosponsoring a conference designed to explore problems relevant to the application of telemetry in selected biomedical situations. The conference will be held by the Engineering Foundation, an organization which develops Research Conferences focused on identifying vital areas of engineering research for urban problems and the public sector. The Biotelemetry Research Conference, to be held August 2-6, 1971, will focus on four application areas:

- Biotelemetry in emergency mobile systems
- Biotelemetry in remote health care
- Biotelemetry in intensive and coronary care units
- Biotelemetry in interinstitutional (hospital-to-hospital) systems

The conference format is structured so that participants can obtain a background of the problem areas and the national resources available for problem solutions. Criteria for biotelemetry systems evaluation and specific problem definitions will also be developed. Finally, participants will propose means for solutions and attempt to match resource needs with resource availability in each of the four areas of application.

The conference will bring together knowledgeable personnel from industry, the government and the biomedical community for constructive interaction in specific problem areas. NASA's wide expertise in biotelemetry systems will add to the range and evaluation of potential solutions developed in this conference.

CONFERENCES TO ENHANCE BIOMEDICAL TECHNOLOGY APPLICATION

Initial discussions have been held with the National Heart and Lung Institute (NHLI) to identify and evaluate NHLI requirements for cardiovascular transducer technology. The Air Force Office of Scientific Research is sponsoring a conference to be held at the University of Kentucky on miniature pressure transducers for physiological studies. NASA has developed small pressure transducers with low surface turbulence characteristics which may be applicable to the needs of NHLI researchers. A special session at the conference will present selected NASA pressure transducer technology.

Plans are underway for a 3-day joint conference between NASA and the American College of Radiology (ACR) which will illustrate possible applications of NASA technology to requirements for improvement in radiological technology. One-half the necessary medical radiology physicists, specialists, and technologists, coupled with an underlying need for improved and automated radiological equipment for both medical diagnosis and therapeutic treatment has led the ACR to define a broad spectrum of areas for technological advancement. Instrumentation, image enhancement/transmission/storage/analysis, nonionizing radiations, systems planning and design and manpower training are some of the requirements identified by the ACR. Five conference topic areas suggested by NASA are: computers and systems; catheters, sensors and materials; image enhancement and recording media; isotope applications and scientific manpower. In support of conference planning The George Washington University Technology Application Group personnel attended a national Conference on Radiology and New Technology to gather further information on radiology technology requirements. This is a significant area for future BATeam program focus because radiology has tremendous impact on medical diagnostic capabilities, therapeutic techniques, and applied biomedical research.

BIOMEDICAL APPLICATIONS ENGINEERING

The University of Virginia's Division of Biomedical Engineering is participating with NASA's Office of Technology Utilization in a small-scale pilot project to modify carefully selected aerospace technology for application to biomedical problems. The University was already cooperating with NASA under the Sustaining University Program and was also developing capabilities in an applied medical engineering program. The objectives of this project are to:

- Assess the general feasibility of adapting aerospace technology to meet the technological needs of specific biomedical problems.

- Review specific bioengineering end item requirements for biomedical needs and assess the relevant capabilities of identified aerospace technologies and the degree of adaptive engineering required to match the technologies with the requirements.

- Carry out a limited number of biomedical applications engineering projects as selected by NASA, the Biomedical Application Teams, and the Division of Biomedical Engineering of the University of Virginia.

- Identify, where appropriate, commercial/industrial capabilities which might serve to adapt aerospace technology to meet biomedical requirements.

A number of proposed biomedical applications engineering projects were reviewed and several pilot projects were initiated during the first year. All of the proposed projects are based on biomedical problems accepted and defined by the NASA Biomedical Application Team Program.

The first technical project currently nearing completion is a prototype implantable urethral valve designed by an aerospace engineer in response to a specific need expressed by practicing urologists. The construction of an improved device for monitoring patient respiratory patterns is also nearing completion and two prototypes will be delivered to Problem Originators for clinical testing.

A low-cost pressure transducer calibration system is also to be studied and constructed. This system will meet a need generated by the growing use of indwelling and external pressure transducers used for patient monitoring in small and large hospitals. Previous devices for calibrating and checking the response of these pressure monitoring devices have been either expensive or imprecise.

A modified Wright Spirometer is also being fabricated as a part of the Application Engineering project. Based on respirometry methods developed at NASA's Electronic Research Center and Flight Research Center, the respirometer provides a digital readout of the amount of air inspired (or expired) by a patient during the previous minute. It is capable of recording flow rates of up to 20 liters per minute and of updating this data every 30 seconds.

The Technology Utilization Office is also considering application engineering efforts on an ultrasonic spirometer first developed and tested at NASA's Electronic Research Center. This instrument is based on a frequency-modulated, ultrasonic transit time technique to measure the velocity of air passing between two ultrasonic sources and receivers. It would allow accurate measurement of both tidal or minute volume. The design allows the patient to breathe through a large diameter low resistance tube, thus the amount of work performed by the patient while breathing is unaffected. As the device has no moving parts or fine capillary tubes, as do other spirometers, it should be far more reliable than instruments previously used to record respiratory function.

Valuable experience has been gained from this pilot project. Along with specific technical end products for biomedical use, it is expected that the

general experience in this area, to be documented, will be of value in the broader context of the bioengineering community.

The Biomedical and Technology Application Teams as well as NASA field centers have recently initiated a number of applications engineering projects. As such, efforts greatly facilitate the ability of the public sector to evaluate and adapt innovative technologies to meet their problems. This facet of the Technology Utilization Program will continue to receive careful guidance, coordination and support.

THE ICMA-NASA TECHNOLOGY APPLICATIONS PROJECT

In late 1970, the International City Management Association (ICMA) and the National Aeronautics and Space Administration (NASA) initiated a joint program designed to apply NASA technology to pressing urban problems. A selected group of ICMA member cities were invited to participate. To date, almost 80 cities, with a total population approaching 20 million, have joined in the initial phases of this program.

Because of the wide range and complex nature of the cities' problems, this experimental program defined its long-term goal as the exploration and development of effective means of applying new technology in a constructive fashion to urban problems. The short-range objectives, which have served as a basis for program design and criteria for future program evaluation, are to:

- Develop an active experimental program to identify and apply aerospace technology relevant to urban problems.

- Improve the policies, strategies and methodologies for the application of technology in the urban environment.

- Assess program contributions, impact and effectiveness in helping cities meet their complex and evolving needs for technology.

As an operational philosophy, the program recognizes that modern science and technology will find its way into local government only if top management reaches for it, understands it, and learns to effectively acquire and use it.

To carry out this complex program, a functional organization--highly flexible in nature--has been created (Figure 56). NASA and the ICMA Technology Applications Program project management share overall coordination responsibilities. The participating cities and selected NASA contractors have specific tasks relating to problem definition and evaluation. Project technical management will be carried out by selected NASA field centers with appropriate expertise. Field centers may develop prototype equipment, or they may prepare prototype specifications so that the ICMA or the cities may contract for prototype development.

An initial working conference planning by NASA and the ICMA was held in October 1970 at the Kennedy Space Center. Representatives from participating cities were given an intensive 2-day exposure to the range of NASA technology and its potential for application to urban problems. City representatives

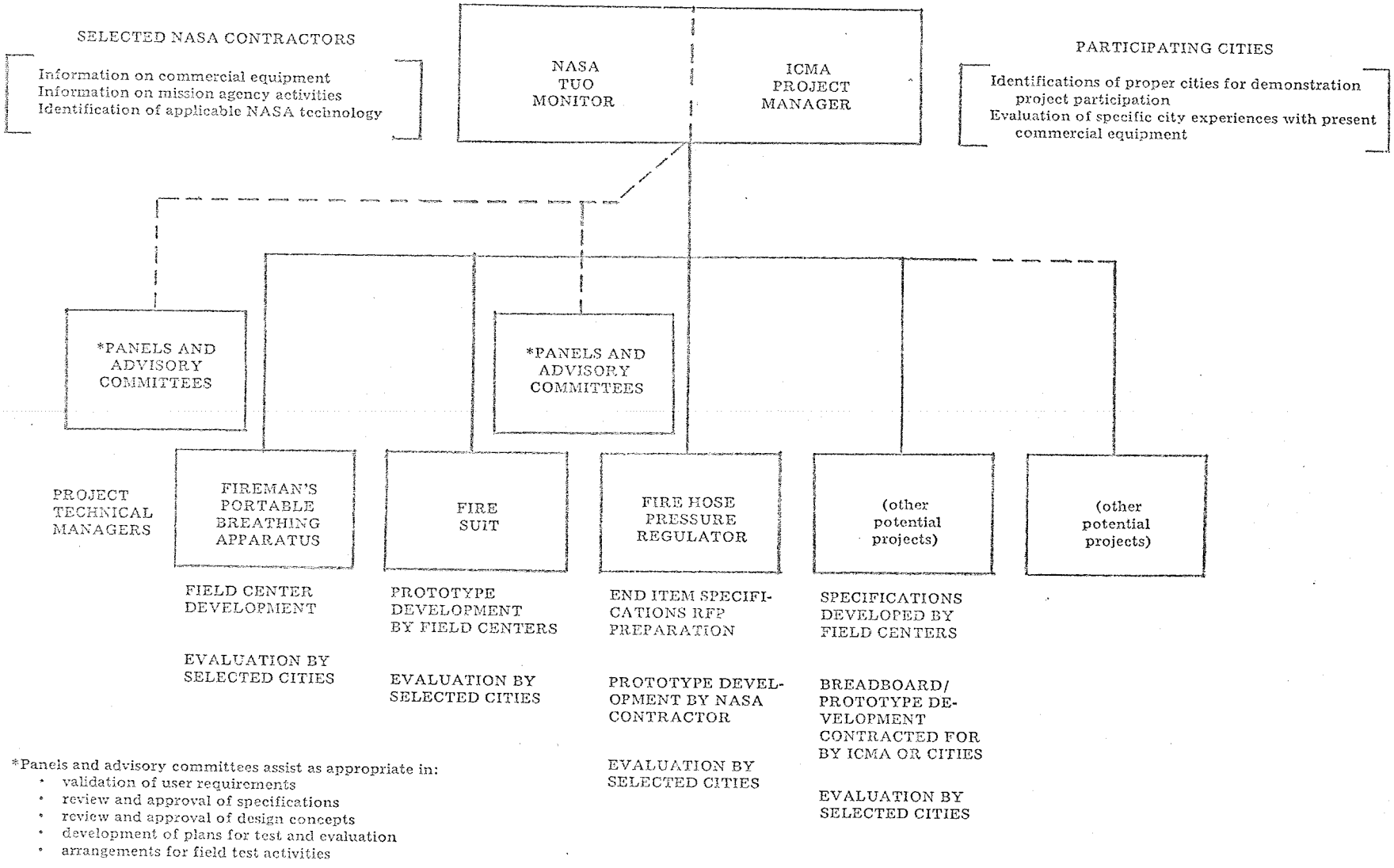


Figure 56. Generalized Functional Chart for ICMA/NASA Projects

were also given intensive work sessions in problem definition skills to facilitate the upcoming task of defining and assigning priorities to urban problems amenable to solution by application of new or improved technology. At the conclusion of the conference the representatives were offered the task of returning to their cities, defining an initial set of problems, and submitting them to the ICMA for review by a coordinating group of city representatives.

An initial set of over 400 problem statements were submitted in January 1971 and independently reviewed by NASA and the ICMA prior to coordinating group review. In late January the coordinating group met, evaluated this set of problems, and reduced it to 45 generic, high-impact urban technology requirements. Major problem areas included communications, law enforcement, fire safety, transportation system control, public works and utilities, health, sewage disposal, solid waste management, and water pollution control. NASA and selected contractors reviewed these problems and redefined an initial set of 15 target problems. Three regional groups of city representatives then met, reviewed and modified many of these more detailed problem statements, and created regional problem priorities. The coordinating group reconvened in April 1971 to agree on a final set of target problems and assign priorities based on stringent review criteria.

Working closely with ICMA Technology Application Program personnel, NASA and selected contractors are now involved in final problem definition, analysis of technology requirements, technology specification, and the initial stages of technology search. Also, other federal agencies which sponsor research and development related to the ICMA problems are being carefully searched to avoid duplication of effort. The program, still in its early stages, will make full use of the problem-solving methodology to search for relevant aerospace technologies from the NASA data base, NASA field center scientists and engineers, and NASA contractors. The initial program plan and related methodologies are periodically reviewed and revised to deal with the often severe technology application barriers present in the urban scene. Figure 57 illustrates the tasks and time scale for a typical urban technology development project. It provides an overview of the time required and the difficult steps which must be taken to achieve effective application of technology in this program.

This ICMA-NASA Technology Applications Program is characterized by its experimental, problem-solving, goal-oriented nature. It is based on systematic use of knowledge gained from past technology applications experience. Interpersonal communication among city, ICMA and NASA personnel is its key behavioral facet. Its crucial role in the urban environemnt is the ability to gain a consensus, an aggregation of needs, from urban representatives on their mutual problems and related technological requirements.

URBAN TECHNOLOGY CONFERENCE

On May 24-26, 1971, the NASA Technology Utilization Office participated in the Urban Technology Conference held in cooperation with and hosted by New York City. The conference was cosponsored by the American Institute of Aeronautics and Astronautics, the National League of Cities/United States Conference of Mayors, and the International City Management Association. The conference aims were to present those technologies suitable for immediate application, and to suggest and create potential areas for future development. The

Figure 57. Example of Urban System Development Schedule

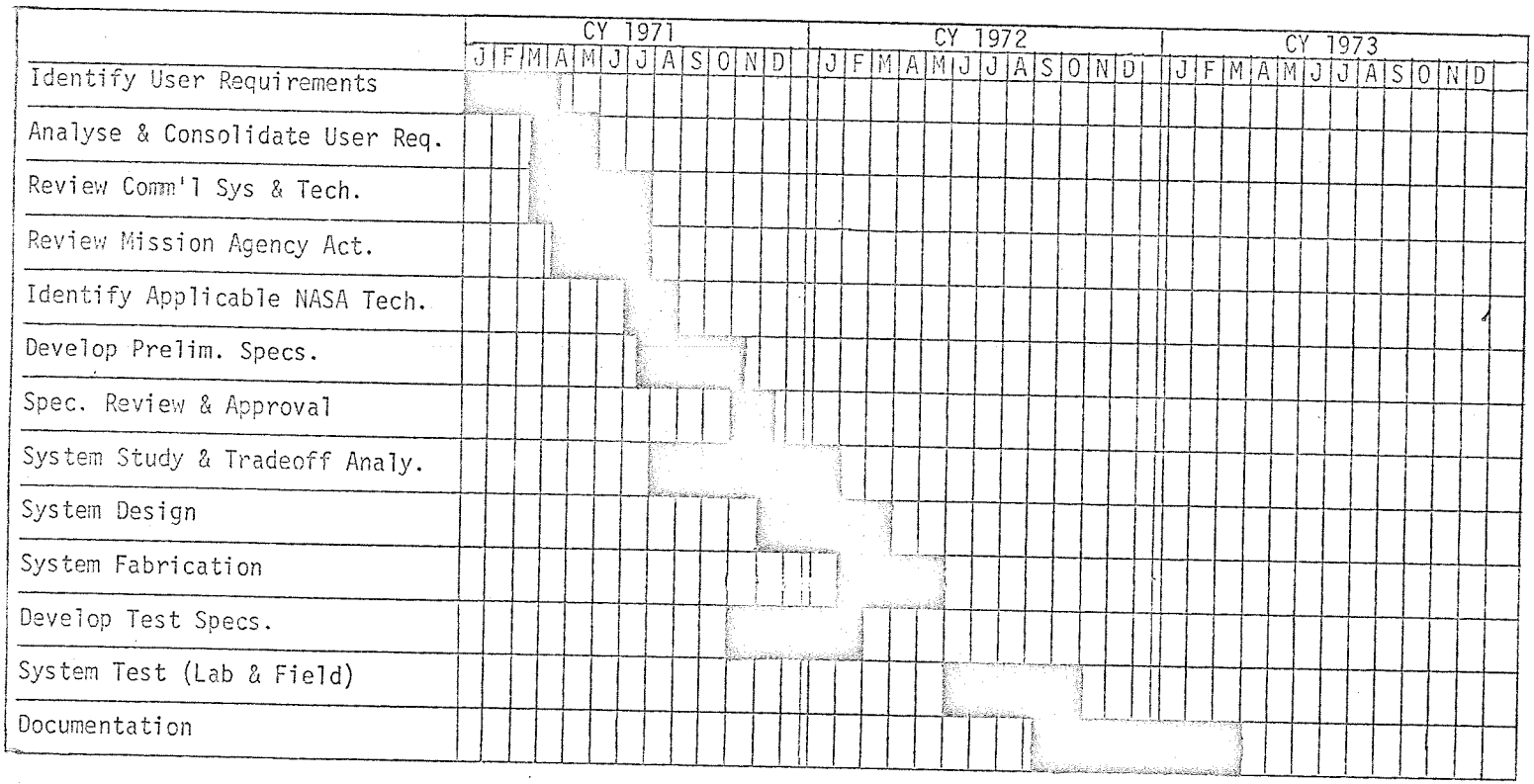


FIGURE 57: Example of Urban System Development Schedule

conference provided interaction between aerospace industry technologists and urban planners. Conference sessions dealt with the problems of management, resources, housing and community development, health and education, transportation, criminal justice, environment, and the politics of technology. The Director of NASA's Technology Utilization Office, Mr. Ronald Philips, presented a paper on the Politics of Technology: An Approach which suggested mechanisms to help the cities improve their technology acquisition efforts. A paper was also presented by the director of the Abt TATeam, Dr. Richard Foster, on Technology Transfer to Urban Problems. Among the NASA technologies displayed were: a school alarm sytem for teacher calls for emergency assistance; an EEG Helmet for evoked response audiometry; a pavement thickness tester for concrete road quality control; a complex coordinator for determining the effects of alcohol, drugs or other toxic substances on subject response time and accuracy; a low-cost smoke detector system for early detection of urban housing fires; an ultrasonic torque wrench to ensure accurate tightening of bolts used in building constructions; a fiber optics indented writing detector for use in criminalistics laboratories; intumescent paints and spray-on foams for housing fire protection and a column chromatograph for rapid detection of heroin derivatives in urine samples.

URBAN CONSTRUCTION SEMINAR

In May 1970, the Abt TATeam hosted an experimental seminar for manufacturers and other building industry representatives. The seminar focused on two unconventional technologies: flat conductor cable and polyurethane spray foam, both of use in construction. The 35 participants included:

- Manufacturers of flat conductor cable and polyurethane foams
- Engineers from NASA's Marshall Space Flight Center
- Systems builders
- Architects
- Representatives of the Department of Housing and Urban Development (HUD)
- Operation Breakthrough (HUD) contractors
- Representatives of the National Bureau of Standards

The seminar approach was highly productive. It created an environment conducive to open discussion of new products by industry people and stimulated interest in the new technologies. A number of the participants decided to consider further applications of foam and cable.

The seminar also identified six factors which determine the success of technology application implementation. These are:

(1) Cultural Acceptability--
New products must meet the consumer's demand for superior quality and acceptability.

(2) Responsibility for Product Performance--
To give the consumer adequate protection, the economic risks and legal liabilities associated with new product introduction must be shared equitably among manufacturers, engineers, architects, and other industry principals. To burden any one market actor with too much responsibility significantly retards innovation.

(3) Development of Standards--
New materials or new applications for conventional products must be evaluated against performance requirements designed around consumer needs and preferences rather than manufacturers' specifications.

(4) R&D Feasibility--
Because NASA technologies must be adapted to the specific requirements of a private sector manufacturer, the costs of research and development must be consistent with the funding capabilities of a potential implementor.

(5) Cost--
Production and marketing costs for new products must be demonstrably low to offset high R&D expenses.

(6) Transfer Mechanism--
Media responsive to the needs of potential users must exist to transmit new technologies to new contexts.

URBAN CONSTRUCTION TECHNOLOGY

An 11-week Summer Faculty Fellowship program, sponsored by the NASA Headquarters Office of University Affairs, will be held at the Marshall Space Flight Center in the summer of 1971. The program will bring together 15 university faculty members, representing various technical disciplines, who will work as a Team to match NASA-developed technology to selected urban construction problems. The New York State Urban Development Corporation (UDC) will assist in the selection of problems to be considered by the faculty members. This program will complement the efforts of the Abt Technology Application Team which has also been working closely with the UDC on urban construction problems.

MINORITY ENTERPRISE PROGRAM

In February 1971, the NASA Technology Utilization Office initiated a contract with the National Progress Association for Economic Development (NPAED), an association formed by the Reverend Leon Sullivan to aid minority groups in the areas of self-ownership and management of commercial enterprises. This contract provides the NPAED with the resources to identify NASA technologies of particular promise for minority manufacturing and marketing enterprises. Following several orientation meetings, the NPAED carried out an extensive review of technologies identified by the Application Teams, the NASA field centers, the NASA patent counsel, and selected advanced evaluation technology files on selected NASA Tech Briefs. Based on a set of market review criteria, the NPAED is analyzing the market potential of an initial set of 85 candidate technologies and will begin to review the technology firsthand at several NASA installations. The objective of this program is to identify a set of NASA technologies which could become part of the product line of existing minority-owned firms, or would justify the creation of new firms. The study results will be fully documented to encourage other interested minority groups to adapt the methodologies and/or technologies resulting from this program.

EFFORTS TO FACILITATE BIOMEDICAL TECHNOLOGY COMMERCIALIZATION

In early 1970, the Association for the Advancement of Medical Instrumentation (AAMI) created the Aerospace Subcommittee of the AAMI Standards Committee to identify and evaluate means of stimulating biomedical industry interest in NASA biomedical technology innovations. The Subcommittee, formed as a result of interaction among the AAMI, the NASA Technology Utilization Office, and the RTI Biomedical Application Team, is composed of representatives from NASA bioinstrumentation personnel, physicians, and the biomedical instrumentation industry. The Subcommittee held its first assembly at the Annual AAMI Meeting in March 1971. During the meeting it received a detailed briefing on the NASA Application Team Program. Prior to its next meeting at the Engineering in Medicine and Biology Conference (fall 1971) the Subcommittee will receive some detailed packages of NASA biomedical technology for its review.

GEORGE WASHINGTON UNIVERSITY

The Biological Sciences Communication Project (BSCP) of The George Washington University Medical Center has been under contract with NASA's Technology Utilization Office since 1965 to provide technical and analytical assistance to the Biomedical Application Team Program. In 1970, this project was expanded to include the Technology Application Teams which were working with public sector agencies. The BSCP's Technology Applications Group provides NASA with continuing general system support for the qualitative and quantitative analysis of the Application Team Program. Detailed monthly reviews of various aspects of the technology transfer process aid in the design and evolution of improved transfer systems. The BSCP supplements the problem identification task of the NAE Subcommittee by investigating and calling to the attention of NASA significant problem areas for the entire Application Team Program. When required, the BSCP recommends to NASA appropriate interfaces with agencies or organizations capable of identifying new problems, or to further the NASA technology transfer efforts. The BSCP has been substantially involved during the last year in interaction with the NAE-CIEBM Project; in the evolution of the ICMA-NASA Technology Applications Project and has assisted in the early phases of the National Progress Association for Economic Development Project.

W. H. CLINGMAN AND COMPANY

Dr. Clingman and his associates have conducted two studies for NASA's Technology Utilization Office. The first study was a detailed, communication-oriented analysis of the Problem Statements prepared by the Application Teams. This study resulted in a special publication, Guidelines for the Preparation of Problem Statements, which defined in detail and illustrated the necessary content of Problem Statements. The Guidelines also suggested techniques for Problem Statement preparation. The second effort, A Study of NASA Literature Search Strategies, was a three-phase study and literature search experiment. It investigated several anomalies in the Application Teams' literature searching that was conducted by the Regional Dissemination Centers. The study recommended a number of procedural innovations designed to improve the program's ability to efficiently access the more than 1,000,000 documents in the NASA Aerospace Data Bank.

BIOMEDICAL PROBLEMS SURVEY

The General Research Corporation, Washington, D.C. Office, conducted a 5-month study for the NASA Technology Utilization Office designed to identify current significant efforts in both biomedical research and clinical medicine for which technological and/or engineering contributions were needed. The study focused on those efforts which are being carried out in an interdisciplinary context where physicians are working closely with engineers and physical scientists toward the solution of biomedical engineering problems. Eight major areas were covered in this exploratory survey:

- Artificial organs and assistive devices
- Automation of clinical laboratories
- Clinical instrumentation
- Hospital information systems
- Medical telecommunication
- Intensive care patient monitoring
- Multiphasic health testing
- Prosthetics, sensory aids, rehabilitation

The specific problem areas identified were compared with current Biomedical Application Team problems and have served as a basis to reallocate program focus where required. The Biomedical Application Teams have begun to strengthen their problem acceptance efforts in several of these areas.

CYBER, INC.

Cyber, an information systems firm, is deeply involved in health information systems design. Recently it undertook a 5-month study to identify NASA technology pertinent to hospital needs in the areas of patient monitoring, hospital information systems, and general management techniques/systems. The final output of this study will document the identified technological requirements and relevant NASA technology in these three areas. The study results will be used to illustrate to interested administrative and medical hospital personnel the potential for use of NASA technology in their environment. It is expected that this exposure will motivate more active acceptance of this technology in the hospital milieu.

CONTINUING AREAS OF PROGRAM EMPHASIS

CONTINUING AREAS OF PROGRAM EMPHASIS

As pointed out in this report, the NASA-sponsored Application Team Program has focused on establishing systematic mechanisms to ensure a continuing and viable effort for the application of aerospace technology to a wide range of society's problems.

To further enhance the program's effectiveness, the Technology Utilization Office will continue to place special emphasis in a number of methodological areas. These are discussed below.

PROBLEM FOCUS AND ACCEPTANCE CRITERIA

The Biomedical and Technology Application Teams have developed problem acceptance criteria pertinent to their particular areas of application efforts. Experience has shown that all of these criteria should not be applied to each problem considered for acceptance. In every case, however, the teams emphasize those factors which help ensure that the Problem Originator has the ability and resources to effectively use the technology which has been identified as a solution to his problem. This emphasis will be continued to avoid the pitfalls of providing a Problem Originator with technology which he cannot further develop or apply, or of diluting program resources by working with inappropriate Problem Originators. Thus, the teams will continue to obtain indepth problems primarily from Problem Originators with an in-house capability to perform required applications engineering or from those Problem Originators who have access to external agencies willing to fund this engineering phase. An example of the first case may be applied to mine safety. The Bureau of Mines performs necessary applications engineering and technical evaluation of solutions developed for their problems. The relationship of the Law Enforcement Assistance Administration (LEAA) to the many local law enforcement agencies and the willingness of LEAA to fund applications engineering serves as a second example.

Additionally, the teams will continue to emphasize the acceptance of those problems which can be described as generic. In this respect the teams describe the generic problem as a major problem area consisting of many technological subproblems. It is at the subproblem level that technology applications are completed. Focus on the generic problems and the resultant applications at the subproblem level will lead to their solution. This generic focus is emphasized as the major means of maximizing the total public impact of the Technology Application Team Program. Close working relationships with authoritative groups and mission agencies will continue to provide valuable guidance.

INTERACTION WITH NASA FIELD CENTERS

One of the important developments of the program's experimental effort is an increasing awareness that communications between the teams and the NASA Field Centers require continuous nurturing. A corresponding development is the recognition of a need for direct and personal communication between the Problem Originator and the NASA scientist or engineer who has knowledge of a potential solution. These two communication factors have led the teams to develop a more intimate relationship with both the Field Center personnel and

the Problem Originators, resulting in improved team familiarity with the aerospace technology within a particular Center. This knowledge enhances the team's ability to develop a solution to a problem earlier in the transfer process. A number of harmonious relationships have developed from this philosophy such as that of Research Center personnel experienced with fire retardant paints and foams, a subsector of the fire safety generic problem area, with the teams.

The personal communication aspect of the technology transfer process will continue to be emphasized as an important element of the Application Team Program in the future. This will shorten the time interval between recognition of a problem and presentation and review of a solution and will ensure the most effective use of the Application Team resources. An additional benefit of this emphasis will be improved quality of problem statement preparation, enhanced by better knowledge of the technology available, the personnel involved, and the Problem Originator's specific requirements.

APPLICATIONS ENGINEERING

As discussed earlier, the task of applications engineering is necessary to effect applications in cases where the Problem Originator lacks the capability or facilities to reengineer technology which is a potential solution to his problem. Applications engineering is not a separate or even major part of the program, but emphasis will be placed on helping facilitate applications engineering for identified solutions with considerable impact in generic problem areas. One desirable means of applications engineering is cooperative effort between government agencies, such as between NASA and LEAA. Another source of cooperative applications engineering effort is the one currently developing between NASA and the Bureau of Standards in the area of life support systems for firemen. Yet another possible applications engineering resource is NASA itself. However, it is important to note that at this stage in the program's evolution each potential solution requiring applications engineering is treated on an *ad hoc* basis. Emphasis will be placed on applications engineering as required to effect high-impact technology applications. Applications engineering is generally not attempted for low-impact problems or for technology which has not reached an acceptable level of development past the conceptual stage.

INFORMATION SEARCH STRATEGIES

Another outgrowth of the experimental facet of the Application Team Program is the development of a methodology for searching the NASA data bank for literature pertinent to a problem and its solution. Early in the program the literature searches were less productive than anticipated because the aerospace "data bank" was developed to locate specific information for aerospace use. The normal aerospace-oriented search strategies did not work well for the Application Teams. An Application Team is seldom able to locate aerospace technology to be applied to a nonaerospace problem by searching on the basis of technological terms remote from the aerospace field. A search strategy must therefore be developed so that technology bearing little or no direct relationship to the problem's technological discipline, but which can be applied to the problem, will be located.

During the past year, emphasis was placed on developing improved search strategies using methods developed under a special study. In essence, this

involves repetitive or parallel searching. First, one locates one or more applicable documents and the keywords or descriptors appended to those documents. These keywords are then used to develop a focused search strategy to locate those documents in the aerospace data bank as well as all other pertinent documents indexed under those terms. This methodology can be applied by the RDCs and is particularly effective when used in conjunction with the NASA Remote Console (RECON) information retrieval system. The emphasis placed on developing highly effective search strategies will be continued as an integral part of the program's operational philosophy.

PEOPLE FACTORS--INTERPERSONNEL COMMUNICATIONS

Earlier, the importance was pointed out for developing direct interchange between the Team personnel, the NASA Field Center scientists and engineers, and the Problem Originators. This is one facet of the people involvement in the Technology Application Program and may be termed the "people factor." It has been recognized by the program as well as by noted communications researchers that the direct interaction of people facilitates the interchange of technical information and provides an indepth technological understanding of the problems. This communications route is necessary, particularly when the existing institutional or administrative mechanisms are cumbersome or inadequate. Continuing emphasis will be placed on the "people factor" to help shorten the time between problem recognition and problem solution and also to provide the level of technological understanding necessary for effective implementation.

The Application Team Program has identified a wide range of significant problem areas and applicable technology. As these significant matches of requirements with capabilities emerge, the effectiveness of applications efforts may often be enhanced by special topic conferences and working sessions. Conferences such as those being planned for the clean room-surgery suite technology, for biotelemetry in medicine, for biomedical tranducers, and for radiology technology are examples of areas of technology application which merit concerted efforts. Conferences which NASA has sponsored in areas such as nondestructive testing, fire safety, portable breathing apparatus, biological quarantine procedures, and many others, add to the general knowledge and technology base.

During this year of operation, a number of opportunities have arisen to enhance program impact and efficiency by means of conferences or symposia. Such opportunities arise as the result of varying circumstances:

- Teams have identified a significant set of technology, capable of impacting one or more generic problem areas, which merit special efforts to diffuse this technology.

- Teams and NASA were invited to cosponsor or participate in conferences with the goal of increasing awareness of program value within user communities.

- The NASA Technology Utilization Office and Teams have broadened the scope of potential program impact by making new user communities aware of opportunities for participation through presentations at conferences and symposia.

Properly designed conferences and conference participation bring together users and providers of technology for creative exchange of knowledge, a process which assists in the definition of significant problems and aids in the creation of alternative solutions. In terms of program resources, it is often more efficient to identify crucial problems and people--and to get a consensus on what the real technological requirement is--by means of a conference.

For these reasons, Application Team Program elements will continue to plan and participate in strategically selected conferences and symposia. These efforts will produce better problem definition, a wider range of alternative problem solutions, and more effective and concentrated disclosure of aerospace technology to both user and industrial communities.

CONCLUSION

There is a rapidly growing tendency for the public to look toward application of existing technology as a means of helping solve problems. There is an increasing awareness of the fact that technology, and aerospace technology in particular, has a major role to play in meeting public needs. This represents a challenge directly related to the process of rational technology selection and application in which the NASA Application Teams are involved. During the forthcoming months continuing emphasis will be placed on both experimental and operational facets of the program in order to study the technology application process and to facilitate the accomplishment of applications and improved documentation of their impact.